Influence of diets containing graded levels of raw and fermented malted sorghum sprouts on rumen ecology, apparent nutrient digestibility and nitrogen utilization of West African Dwarf goats

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Abstract

A feeding trial was conducted to investigate the rumen fermentation parameters, digestibility and nitrogen utilization of West African Dwarf (WAD) goats fed diets containing graded levels of malted sorghum sprouts (MSP) in raw (RMSP) and fermented (FMSP) forms incorporated into the concentrate diet at 0, 25 and 50% to formulate six experimental diets using 2×3 factorial layout in a completely randomized design. A total of 24 WAD goats were randomly allotted to six dietary treatments for 12 wk, with four animals per treatment. Data were collected on rumen ecology, digestibility, and nitrogen utilization parameters. Results showed that processing methods and levels of MSP inclusion influenced ($p<0.05$) all the rumen environment parameters except rumen pH. Rumen ammonia nitrogen (NH_3-N) concentration increased ($p<0.05$) from 6.32 to 7.45 mg/100mL across the dietary treatments as the MSP inclusion level increased. Inclusion level of MSP influenced ($p<0.05$) total bacteria count (TBC), total coliform count (TCC), total fungi count (TFC) and protozoan. Animals fed diet containing 50% MSP based diet recorded the highest values of TBC (7.26×10^6 cfu/mL), TCC (0.66×10^6 cfu/mL) and TFC (0.66×10^6cfu/mL). The main and interactive effects of the processing methods and MSP inclusion level significantly ($p<0.05$) influenced the nutrient digestibility. The main effect of the processing methods employed significantly influenced the digestibility values. Animals fed FMSP based diet recorded higher dry matter (69.61%) and crude protein (68.09%) digestibility values when compared with those fed RMSP based diet. Animals fed 50% FMSP based diet elicited the highest dry matter digestibility (74.48%) and crude protein digestibility (73.10%). The main effect of processing methods and levels of MSP inclusion significantly ($p<0.05$) influenced the nitrogen utilization in which goats fed FMSP based recorded higher value (61.28%) while goats in 25% FMSP or MSP recorded the highest value (60.89%). Significant ($p<0.05$) interaction effect was obtained for nitrogen utilization parameters observed. Goats fed 50% FMSP based diet recorded the highest nitrogen utilization value (70.01%). It can be concluded that fermented malted sorghum sprouts could be used up to 50% in WAD goats' diet without any adverse effect on the rumen ecology, nutrient digestibility, and nitrogen utilization of the animals.

Keywords: Malted sorghum sprouts, non-conventional feedstuff, WAD goats, volatile fatty acids

Introduction

The major constraint in small ruminant production is the availability of good quality forages round the year. Even the few available ones gradually become low in nutritive value during the dry season period (Njoya *et al.,* 2005). One possible way to alleviate this problem is how the production can be sustained in the Tropics such as that ruminants can be fed with non-conventional feedstuffs, which may probably serve as alternative feed resources in the dry season. The use of several crop residues (maize cobs and husk, cassava peel, etc.), other agricultural by-products (vinnase, malted sorghum sprouts, grape pomace, etc.) and browse plants to improve livestock production in the Tropics has been well documented (Olafadehan *et al.,* 2011; Yusuf *et al.,* 2018). Malted sorghum sprouts (MSP), a non-conventional feedstuff with a high nutritive profile, has been established to be useful feed source in rabbits (Jegede *et al.,* 2006), pigs (Fanimo and Akinola, 2006) and birds (Fafiolu *et al.,* 2016). Saka *et al. (*2016) reported that MSP contained 88.79% dry matter 26.38% crude protein 2.35% ether extract 5.21% ash 51.06% nitrogen-free extract 49.57% neutral detergent extract, 31.25% acid detergent fibre, 3.92% acid detergent lignin, 18.32% hemicellulose and 27.33% cellulose. The anti-nutritional factors, including tannin, cyanogenic glucoside, phytic acid, trypsin inhibitor, and oxalate, were reportedly found in MSP (Mohammed *et al.,* 2011). Waghorn (2008) reported that tannin affected animal performance as it caused a reduction in feed intake and diet degradability. Detoxifying non-conventional feedstuffs might be a good means of reducing the level of anti-nutritional factors and thus increases the nutritive value of MSP (Ogbonna, 2012). The fermentation of MSP was reported to reduce the anti-nutritional factors as it increased the digestibility of plant proteins (Pranoto *et al.,* 2013). Ruminant animals are known to obtain their energy and essential nutrients from ingested feed through the ability of ruminal microorganisms to produce enzymes necessary for fermentation processes (Burns, 2008). However, changes in the rumen community can significantly affect the health and productivity of the host ruminant (Russell, 2002). This study was therefore designed to investigate rumen ecology, nutrient digestibility and nitrogen utilization of West African Dwarf goats fed diets containing graded levels of raw and fermented MSP.

Materials and Methods

Site of Experiment

The experiment was conducted at the Teaching and Research Farm of the Federal College of Animal Health and Production Technology, Moor Plantation, Ibadan, in the South-western part of Nigeria. The area lies within the rain forest ecological zone. It falls within longitude and latitude of 7^0 27^l and 3^0 25^l, respectively at altitude of 200- 300 m above the sea level with an annual rainfall of about 1250 mm: the temperature and relative humidity range from 30 – 35^0C and 76 – 84%, respectively.

Experimental Animals and Their Management

A total of 24 West African Dwarf (WAD) goats aged 6–8 mo with live weights between 7-9 kg were used for this study. The animals were housed intensively in well-ventilated individual pens, disinfected with izal solution two wk before the experiment. On arrival, the goats were quarantined for 30 d, and during this period, they were given prophylactic treatments consisting of intra-muscular injection of oxytetracycline long acting (1ml/10 kg BW) and vitamin B complex to ensure the good condition of the animals. They were also routinely dewormed with 1ml/10 kg BW of Albendanzole and injected with 0.5 ml/10 kg BW of Ivermectin to eliminate both internal and external parasites, respectively. Homologous *Pesti des petit ruminant* (PPR) vaccine was administered against PPR disease. The animals were adapted to pen environment after which data were collected for 84 d. Fresh cool, clean water was also supplied *ad libitum*. After the adaptation period, the 24 animals were balanced as closely as possible for body weight and randomly allotted to one of the six dietary treatments. The diets as presented in Table 1 for each treatment were fed with a basal diet of *Panicum maximum*.

Fermentation of Malted Sorghum Sprouts and Preparation of Experimental Diet

Malted sorghum sprouts (MSP) were purchased in dried form from Taibod Nigeria Limited, a reputable agro-allied industry at Ijoko Otta in Ogun State, Nigeria. MSP purchased was divided into two equal parts such that the first part was not treated referred to as raw, while the second part was naturally fermented. Fermentation involved the use of water and polythene bag; water was mixed with the dried malted sorghum sprouts at a ratio of 2:1 so that the entire sprouts were moistened. The mixture was then transferred into air-tight nylon bags and fermented under room temperature for 96 h. After that, it was then spread on the concrete floor for sun drying, according to Fanimo and Akinola (2006). The raw and fermented MSP prepared were mixed with concentrate at varying levels of 0, 25, and 50%, respectively, to formulate six diets as indicated in Table 1. Other ingredients in the diets included limestone, maize bran, wheat offal, salt, and premix.

Table 1: Ingredient and composition of the experimental concentrates diet

Parameters[3] (%)	RMSP[1]			FMSP[2]		
	0%	25%	50%	0%	25%	50%
Maize bran	40.00	40.00	40.00	40.00	40.00	40.00
Wheat offal	54.25	29.25	4.25	54.25	29.25	4.25
MSP	-	25.00	50.00	-	25.00	50.00
Premix	0.25	0.25	0.25	0.25	0.25	0.25
Limestone	5.00	5.00	5.00	5.00	5.00	5.00
Salt	0.50	0.50	0.50	0.50	0.50	0.50
Total	100.00	100.00	100.00	100.00	100.00	100.00
Determined analysis						
Dry matter	88.20	90.08	91.86	88.20	90.69	92.65
Crude protein	15.78	17.06	17.21	15.78	16.22	16.93
NFE	54.26	54.47	55.81	54.26	55.43	55.83
Ether extract	3.60	3.63	3.75	3.60	3.90	4.05
Ash	7.91	8.19	8.32	7.91	7.97	8.10
NDF	42.70	43.05	43.81	42.70	44.40	44.60
ADF	26.96	27.90	28.77	26.96	29.44	29.66
ADL	8.96	9.06	9.40	8.96	11.11	11.16
Hemicellulose	15.04	15.16	15.74	15.04	14.74	14.80
Cellulose	17.90	18.56	18.94	18.56	18.64	19.37

[1]RMSP, [2]FMSP

[3]NFE: Nitrogen free extract, NDF: Neutral detergent fibre, ADF: Acid Detergent fibre, ADL: Acid detergent lignin

Experimental Design

A total of 24 West African Dwarf goats aged 6-8 mo were divided on weight equalization basis into six treatment groups of four bucks each in a 2×3 factorial arrangement.

Data Collection

Feed Intake and Live Weight Changes

The growth of the animals in response to the experimental diets was monitored by taking their pre-experimental body weights, followed by weighing every wk before feeding. Feed fed daily to each animal was recorded, and refusal was considered and recorded to compute feed intake on a daily basis.

Digestibility Trial and Nitrogen Balance

The digestibility trial was conducted using 18 goats (3 goats per treatment) two wk to the end of the 12-week growth trial. The goats were housed in individual metabolic cages with a slated floor equipped with facilities for separate collection of faeces and urine. The adaptation period of 7 d was followed by a 7-day total faeces and urine collection. Subsamples of daily feed offered, refusals, and faeces voided per goat were collected and weighed. At the end of the collection period, the faeces collected from each goat were thoroughly mixed, to have two subsamples. One of the samples was used for estimating dry matter (DM) by oven-drying at 105°C for 24 h, while the second sample was oven-dried at 60°C for 72 h and milled for chemical analysis.

Urine was collected daily in plastic bottles containing a solution of 10% H_2SO4 to prevent ammonia-N loss and maintain pH below 3.0. A 10% aliquot was taken from each goat's samples for nitrogen determination.

Nitrogen Utilization

Nitrogen retention was calculated by subtracting faecal and urinary nitrogen from nitrogen intake. While nitrogen utilization was calculated as:

$$\text{Nitrogen Utilization (NU)} = \frac{\text{N retention}}{\text{N intake}} \times 100$$

Rumen fluid was collected at the beginning and end of the experiment from the three randomly selected experimental goats per treatment through the oesophagus by the use of a suction tube, as described by Santra *et al.* (2012). The pH was immediately determined at the point of collection by a portable digital pH meter. The portable digital pH meter was stabilized in distilled water with a specific pH recommendation before been used for reading. About 30 mL of rumen fluid was collected and filtered through four layers of cheesecloth in such a way the filtered fluid was divided into three parts, kept in sample bottles, and stored in a freezer for rumen ammonia nitrogen and volatile fatty acid analyses.

Sample of the rumen filtrate was acidified with 1ml of a 5% (v/v) tetraoxosulphate (vi) acid solution and then stored at -20^{0}C in an air-tight bottle for subsequent determination of total volatile fatty acids (VFA) concentration which was determined by steam distillation process using Markham micro-distillation apparatus as reported by Yusuf *et al.* (2013). Individual VFAs (propionic, acetic and butyric acid) was determined using gas chromatography as described by Mebrahtu and Tenaye (1997). Ammonia nitrogen concentration and identification were determined as described by Lanyansunya *et al*. (2007).

Approximately 2 mL of the rumen liquor was siphoned into a 30 mL corked test tube containing 20 mL of sodium acetate buffer at pH 8.2. The mixture was thoroughly shaken to ensure complete trapping of ammonia nitrogen. The mixture was filtered through a Whatman No. 42 filter paper into a 30-mL test tube. The absorbance of the sample, as well as working standards, were read on a 21D spectrophotometer at a wavelength of 630 nm (AOAC, 2002).

Chemical Analysis

Sub-samples of feed offered and faeces were ground to pass a 1-mm sieve screen using a laboratory hammer mill and analyzed for dry matter, crude protein, ether extract and ash contents (AOAC, 2002). Fibre fractions of neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were determined according to Van Soest *et al*. (1991). Cellulose was calculated from the difference between ADF and ADL while hemicellulose was calculated as the difference between NDF and ADF.

Statistical Analysis

Data obtained were subjected to analysis of variance using 2×3 factorial arrangement in a completely randomized design. Significant means of variables were separated using Duncan multiple range test (SAS, 2004).

Results and Discussion

Main Effect of Processing Methods and Malted Sorghum Sprouts Inclusion Levels on *the Apparent Nutrient Digestibility (%) of West African Dwarf Goats*

Table 2 shows the main effect of processing methods and MSP inclusion levels on the apparent nutrient digestibility of West African Dwarf goats. The dry matter, crude protein, hemicellulose (HEM), and acid detergent fibre (ADF) were significantly ($p<0.05$) influenced by processing methods while other parameters observed showed no significant difference among treatments. Dry matter digestibility ranged from 61.26% to 69.61% in which goats fed diet containing FMSP exhibited higher value compared to those fed RMSP based diets. Crude protein digestibility followed a similar pattern of variation observed in dry matter digestibility in the goats. The acid detergent fibre and hemicellulose digestibility in goats fed RMSP was higher ($p<0.05$) than those fed FMSP.

However, the main effect of MSP inclusion levels showed no significant difference on most of the parameters observed except dry matter and ash digestibility that were significantly ($p<0.05$) influenced by the levels of MSP inclusion in the diet. Animals that consumed diet containing 25% MSP significantly recorded the best dry matter digestibility (68.39%) followed by those fed 50% MSP (66.04%) and 0% MSP (61.87%). Ash digestibility was also significantly influenced ($p<0.05$) by the MSP inclusion level in which goats fed 0% MSP exhibited the highest value (89.21%) while the lowest ash digestibility (87.47%) was observed in goats fed 25% MSP.

Table 2: Main effect of processing methods and malted sorghum sprouts inclusion levels on the apparent nutrient digestibility (%) of West African Dwarf goats

Parameters	Processing methods			Level of MSP inclusion			
	RMSP	FMSP	SEM±	0%	25%	50%	SEM±
Dry matter	61.26^{b}	69.61^{a}	1.15	61.87^{b}	68.39^{a}	66.04^{ab}	1.41
Crude protein	61.16^{b}	68.09^{a}	1.26	64.19^{b}	64.88^{b}	84.80^{a}	1.55
Ether extract	84.80	83.18	0.56	84.31	84.49	83.18	0.63
Ash	88.75	88.13	0.43	89.21^{a}	87.47^{b}	88.64^{ab}	0.52
NFC	43.78	43.08	1.86	42.67	43.79	43.83	2.27
NDF	69.75	66.94	2.20	66.94	67.51	70.58	2.69
ADF	66.06^{a}	56.95^{b}	1.94	65.58	60.51	58.41	2.37
ADL	45.94	43.76	1.37	45.68	44.34	44.54	1.68
Hemicellulose	56.83^{a}	48.98^{b}	1.97	56.59	52.06	50.07	2.41
Cellulose	62.79	59.19	2.31	61.92	64.88	56.17	2.83

[ab] Means with different superscripts along the same row are significantly different ($P< 0.05$)
RMSP: Raw Malted Sorghum Sprouts, FMSP: Fermented Malted Sorghum Sprouts, NFC: Non-Fibre Carbohydrate.
NDF: Neutral Detergent Fibre, ADF: Acid Detergent Fibre ,ADL: Acid Detergent Lignin

Interactive Effect of Processing Methods and Inclusion Levels Of Malted Sorghum Sprouts on the Apparent Nutrient Digestibility (%) of West African Dwarf Goats

The interactive effect between processing methods and MSP inclusion levels on the apparent nutrient digestibility of West African Dwarf goats is presented in Table 3. The parameters observed were significantly (p<0.05) influenced by the dietary treatment except the neutral detergent fibre and acid detergent lignin. Dry matter digestibility varied significantly (p<0.05) across the dietary treatments. Animals offered diet containing 50% FMSP had the highest value (76.48%) while the goats that consumed diet containing 50% RMSP exhibited the lowest value (55.60%). The crude protein digestibility value ranged from 56.50% to 73.10%. Animals fed diet containing 50% FMSP recorded the highest values (73.10%) followed by those fed 25% FMSP (67.85%), 0% RMSP (65.08%), 0% FMSP (63.31%), 25% RMSP (61.91%) and 50% RMSP (56.59%), respectively. Ash digestibility values ranged from 90% in 50% RMSP to 86.98% in 25% RMSP. Animals offered diet containing 50% RMSP had the highest value (90.00%) followed by those fed diets containing 0% RMSP (89.27), 0% FMSP (89.15) and 25% FMSP (87.96) which were statistically similar (p>0.05). They were however higher (p<0.05) than those on diet containing 50% FMSP (87.29%), and 25% RMSP (86.98%) which had similar (p>0.05) ash digestibility value. Goats fed diet containing 50%RMSP (85.23%), 25% RMSP (85.02%),0% FMSP (84.46%) and 0% RMSP (84.17%) recorded similar (p>0.05) in ether extract digestibility values; however, they were significantly higher (p<0.05) than those consumed diets containing 25% FMSP (83.95%) and 50% FMSP (81.13%) was the least acid detergent fibre (ADF) and hemicelluloses (HEM) digestibility observed in this study followed a similar pattern of variation as observed in ether extract digestibility. Non fibre carbohydrate (NFC) and cellulose (CEL) digestibilities were also influenced significantly (p<0.05) across the treatments with digestibility values ranged from 36.39% in 0% FMSP to 49.37% in 0% FMSP and 46.66% in 50% FMSP to 68.98% in 25% FMSP, respectively.

Table 3: Interactive effect of processing methods and inclusion levels of malted sorghum sprouts on the apparent nutrient digestibility (%) of West African Dwarf goats

Parameters	RMSP			FMSP			
	0%	25%	50%	0%	25%	50%	SEM±
Dry matter	61.87^{c}	66.30^{bc}	55.60^{d}	61.87^{c}	70.49^{b}	76.48^{a}	1.99
Crude protein	65.08^{b}	61.91^{bc}	56.50^{c}	63.31^{bc}	67.85^{ab}	73.10^{a}	2.19
Ether extract	84.17^{a}	85.02^{a}	85.23^{a}	84.46^{a}	83.95^{ab}	81.13^{b}	0.97
Ash	89.27^{ab}	86.98^{b}	90.00^{a}	89.15^{ab}	87.96^{ab}	87.29^{b}	0.74
NDF	68.20	66.28	74.75	65.68	68.74	66.41	3.80
ADF	68.91^{a}	62.88^{a}	66.41^{a}	62.24^{a}	58.15^{ab}	50.44^{b}	3.35
ADL	45.68	44.27	47.87	45.68	44.41	41.20	2.38
Hemicellulose	56.59^{a}	55.51^{a}	58.39^{a}	56.59^{a}	48.61^{ab}	41.75^{b}	3.41
Cellulose	61.92^{a}	60.78^{a}	65.68^{a}	61.92^{a}	68.98^{a}	46.66^{b}	4.00

^{ab}Means with different superscripts along the same row are significantly different (P< 0.05)

RMSP: Raw Malted Sorghum Sprouts, FMSP: Fermented Malted Sorghum Sprouts, NDF: Neutral Detergent Fibre

ADF: Acid Detergent Fibre, ADL: Acid Detergent Lignin

Main Effect of Processing and Malted Sorghum Sprouts Inclusion Level on the Nitrogen Utilization of West African Dwarf Goats

The main effect of processing methods and MSP inclusion level on the nitrogen utilization of West African Dwarf goats is indicated in Table 4. All the parameters measured were significantly ($p<0.05$) influenced by the processing methods employed except the urinary nitrogen (N) output that showed no significant variation. Nitrogen (N) intake increased significantly ($p<0.05$) from 6.18 g/day in that diet containing RMSP to 7.42 g/day in the diet containing FMSP. Faecal nitrogen (N) output values ranged from 2.00 g/day to 2.19 g/day for goats fed diet containing RMSP recorded significantly ($p<0.05$) higher values compared to those fed FMSP. Nitrogen retention and utilization were also significantly ($p<0.05$) influenced but followed a similar trend as observed in N intake.

Level of inclusion of malted sorghum sprouts (MSP) significantly ($p<0.05$) affected all the parameters observed in this study. Animals offered diet containing 50% MSP had the highest values in nitrogen intake followed by those fed diet containing 25% MSP and the least values were observed in the diet containing 0% MSP. Faecal nitrogen (N) output of animals fed diet containing 0% MSP elicited the higher value (2.23 g/day) than those fed diet containing 25% MSP (2.02 g/day) and 50% MSP (2.05 g/day) which were statistically similar ($p>0.05$) in value. The urine nitrogen (N) output, nitrogen retention and nitrogen utilization of goats fed diet containing 25% MSP and 50% MSP were similar ($p>0.05$); they were, however, higher ($p< 0.05$) than those on diet containing 0% MSP.

Table 4: Main effect of processing and malted sorghum sprouts inclusion level on the nitrogen utilization of West African Dwarf goats

Parameters	Processing methods			Level of MSP inclusion			
	RMSP	FMSP	SEM±	0%	25%	50%	SEM±
N intake (g/day)	6.18^b	7.42^a	0.21	5.75^b	7.30^a	7.36^a	0.26
<u>N excretion (g/day)</u>							
Faeces	2.19^a	2.00^b	0.04	2.23^a	2.02^b	2.05^b	0.05
Urine	0.67	0.75	0.06	0.55^b	0.81^a	0.77^a	0.07
Total N output (g/day)	2.86	2.75	0.09	2.78	2.83	2.83	0.11
N retention (g/day)	3.32^b	4.67^a	0.24	2.97^b	4.47^a	4.54^a	0.03
N utilization (%)	53.14^b	61.28^a	1.89	51.40^b	60.89^a	59.34^a	2.32

^{ab}Means with different superscripts along the same row are significantly different (P< 0.05)
N: Nitrogen RMSP: Raw Malted Sorghum Sprouts. FMSP: Fermented Sorghum Sprouts.

Interactive Effect of Processing Methods and Malted Sorghum Sprouts Inclusion Levels on the Nitrogen Utilization of West African Dwarf Goats

The interaction of processing methods by the MSP inclusion levels on the nitrogen utilization is presented in Table 5. All the parameters of interest observed in this study were significantly ($p<0.05$) influenced. Nitrogen intake values ranged from 5.75 g/day in 0% MSP to 8.64 g/day in 50% FMSP. More so, nitrogen intake of goats offered diets containing 25% FMSP and 50% FMSP were similar ($p>0.05$); they were however higher ($p<0.05$) than those fed diet containing 0% RMSP, 0% FMSP, 25% RMSP and 50% RMSP which recorded similar ($p>0.05$) nitrogen intake values. Faecal and urine nitrogen (N) output observed in this study varied significantly ($p<0.05$) across the dietary treatments which ranged from 1.78-2.31g/day and 0.55-0.95 g/day, respectively. However, goats on diet containing 50% FMSP exhibited the highest nitrogen retention value of 6.11g/day followed by those fed diets containing 25% FMSP (4.94 g/day), 25% RMSP (4.01 g/day) and the least value of 2.97 g/day was obtained in the diet containing 0% RMSP, thus it was statistically similar ($p>0.05$) to the diets containing 50% RMSP (2.98 g/day) and 0% FMSP (2.97 g/day). Nitrogen utilization differed significantly ($p<0.05$) among goats subjected to different dietary treatments with goats fed 50% FMSP (70.01) recorded the highest value and the least value was observed with goats fed 50% RMSP (48.67 g/day).

Table 5: Interactive effect of processing methods and malted sorghum sprouts inclusion levels on the nitrogen utilization of West African Dwarf goats

Parameters	RMSP			FMSP			
	0%	25%	50%	0%	25%	50%	SEM±
N intake (g/day)	5.75^{b}	6.72^{b}	6.08^{b}	5.75^{b}	7.88^{a}	8.64^{a}	0.37
<u>N excretion (g/day)</u>							
Faeces	2.23^{ab}	2.04^{b}	2.31^{a}	2.23^{ab}	2.00^{b}	1.78^{c}	0.07
Urine	0.55^{b}	0.68^{ab}	0.79^{ab}	0.55^{b}	0.95^{a}	0.76^{ab}	0.10
Total N output (g/day)	2.78^{ab}	2.72^{ab}	3.10^{a}	2.78^{ab}	2.95^{ab}	2.54^{b}	0.15
N retention (g/day)	2.97^{c}	4.01^{bc}	2.98^{c}	2.97^{c}	4.94^{ab}	6.11^{a}	0.42
N utilization (%)	51.40^{cd}	59.35^{bc}	48.67^{d}	51.40^{cd}	62.42^{ab}	70.01^{a}	3.27

^{abcd}Means with different superscripts along the same row are significantly different ($P< 0.05$)
N: Nitrogen RMSP: Raw Malted Sorghum Sprouts. FMSP: Fermented Sorghum Sprouts.

The main effect of processing methods and MSP inclusion level on rumen environmental parameters of WAD goats is indicated in Table 6. Processing methods of malted sorghum sprouts (MSP) significantly ($p<0.05$) influenced all the parameters observed in this study except the pH that indicated no significant variation ($p>0.05$). At the end of the experiment, it was observed that there was an increase in rumen ammonia nitrogen (NH_3-N) value obtained both in the diets containing raw and fermented malted sorghum sprouts. Rumen ammonia nitrogen (NH_3-N) value of animals fed diets containing both raw and fermented MSP were similar ($p>0.05$) but goats fed diets containing RMSP recorded higher ($p<0.05$) variation compared to those that consumed diets containing FMSP. Reduced values were observed in acetic acid, butyric acid, propionic acid, lactic acid and total volatile fatty acid (TFVA).

However, the main effect of MSP inclusion level revealed significant effect on all the parameters monitored in this study. The pH value of animals on diets containing 0% MSP and 25% MSP were statistically similar ($p>0.05$) but they were higher ($p<0.05$) than those on diet containing 50% MSP at the end of the experiment. Goats fed diet containing 25% MSP had highest variation value (0.29) followed by 0% MSP (0.04) and 50% MSP (0.05). Reduced values were observed in pH, acetic acid, propionic acid, lactic acid and TVFA while rumen ammonia nitrogen (NH_3-N) and butyric acid did not decrease at the end of the experiment. Final rumen ammonia nitrogen (NH_3-N) showed significant ($p<0.05$) difference between treatment groups with animals on diet containing 50% MSP had highest value (7.36 mg/dL) followed by those on diet containing 25% MSP (7.11 mg/dL) and 0% MSP (6.32 mg/dL), respectively. Animals fed diet containing 0% MSP recorded the highest variation value (1.14 mg/100mL) than those that consumed diets containing 25% MSP and 50% MSP which were statistically similar. Final acetic acid concentrations were 94.13, 90.00 and 64.75 mmol/100mL for diets containing 0%, 25% and 50% MSP, respectively, in which animals on diets containing 0% and 25% MSP were similar ($p>0.05$) but they were higher ($p<0.05$) than those on diet containing 50% MSP. Propionic acid and TVFA followed similar trend as observed in acetic acid. Final lactic acid value observed in this study showed significant ($p<0.05$) differences across the treatments in which animals fed diets containing 0% and 25% MSP recorded similar value ($p>0.05$) but they were however higher ($p<0.05$) than those fed diet containing 50% MSP. Goats fed diet containing 0% MSP had the highest ($p<0.05$) value of variation followed by those fed diets containing 50% and 25% MSP, respectively.

Table 6: Main effect of processing methods and malted sorghum sprouts inclusion levels on rumen environment parameters of West African Dwarf goats

Parameters	Processing Methods			Level of MSP inclusion			
	RMSP	FMSP	SEM±	0%	25%	50%	SEM±
Ph							
Onset	5.04	5.01	0.03	5.17^{a}	4.73^{b}	5.18^{a}	0.04
Final	4.88	5.00	0.05	5.13^{a}	5.01^{a}	4.68^{b}	0.06
Variation	-0.16	-0.01	0.06	-0.04^{b}	0.29^{a}	-0.05^{c}	0.07
NH_3–N (mg/100mL)							
Onset	5.93^{b}	6.21^{a}	0.06	5.19^{c}	6.37^{b}	6.66^{a}	0.08
Final	6.93	6.93	0.06	6.32^{c}	7.11^{b}	7.36^{a}	0.07
Variation	1.00^{a}	0.72^{b}	0.08	1.14^{a}	0.74^{b}	0.71^{b}	0.09
Acetic acid (mmol/100mL)							
Onset	132.00	116.08	8.15	134,50	130.50	107.13	9.99
Final	74.13	91.79	2.38	94.13^{a}	90.00^{a}	64.75^{b}	2.92
Variation	-57.88^{b}	- 24.29^{a}	8.39	-40.38	-40.50	-42.38	10.29
Butyric acid (mmol/100mL)							
Onset	40.54	32.22	2.89	39.03	38.68	31.43	3.53
Final	47.74	37.62	4.69	55.61^{a}	40.07^{ab}	32.37^{b}	5.74
Variation	7.20	5.41	4.61	16.58	1.39	0.94	5.64
Propionic acid (mmol/100mL)							
Onset	87.67	77.25	5.41	89.50	87.00	70.88	6.62
Final	53.42	62.08	1.29	63.75^{a}	63.75^{a}	45.75^{b}	1.58
Variation	-34.25^{b}	- 15.17^{a}	5.40	-25.75	-23.75	-25.13	6.61
TVFA (mmol/100mL)							
Onset	353.10	310.81	21.75	359.51	349.74	268.63	26.64
Final	207.82	249.09	5.87	255.69^{a}	250.86^{a}	178.83^{b}	7.20
Variation	- 145.28^{b}	- 61.73^{a}	22.42	- 103.85	-98.89	- 107.79	7.20
Lactic acid							
Onset	178.58	152.25	16.05	146.50	190.63	159.13	19.66
Final	106.67	137.67	7.45	143.50^{a}	134.75^{a}	88.25^{b}	9.12
Variation	-71.92^{b}	- 14.58^{a}	17.45	-3.00^{a}	- 55.88^{ab}	-70.88^{b}	21.37

^{abc} Means with different superscripts along the same row are significantly different (P< 0.05)
TVFA: Total Volatile Fatty Acids NH_3–N: Ruminal Ammonia Concentration

Presented in Table 7 is the interactive effect of processing methods and MSP inclusion level on rumen environmental parameters of WAD goats. All the rumen environmental parameters observed were significantly (p<0.05) influenced by the interaction between processing methods and MSP inclusion level. More so, there was a reduction in all the parameters observed except the rumen ammonia nitrogen (NH_3-N) and butyric acids which did not reduce at the end of the experiment. The final pH values of animals offered diet containing 0% RMSP and 0% FMSP recorded the highest value while the lowest value was observed in animals on diet containing 50% RMSP. There was no reduction in the pH value obtained in animals on diet containing either 25% RMSP or 25% FMSP at the end of the feeding trial. Goats on diet containing 25% FMSP had the highest variation value while the lowest value was observed in animals on diet containing either 50% RMSP or 50% FMSP. Increment was observed in the final ammonia values which ranged from 6.32 mg/100mL in diet containing 0% MSP to 7.45 mg/100mL in diet containing 50% RMSP. Variation in (NH_3-N) value of animals on diets containing 0% RMSP, 0% FMSP and 25% RMSP were similar ($p>0.05$), they were however higher ($p<0.05$) than those on diet containing 50% RMSP which in turn had higher ($p<0.05$) than those on diets containing 25% and 50% FMSP. At the end of the experiment, goats that consumed diet containing 25% FMSP recorded the highest value (125.75 mmol/100mL) and the lowest value was observed in animals on diet containing 25% RMSP (54.25 mmol/100mL). More so, goats fed 25% FMSP had the highest ($p<0.05$) variation while the lowest value was observed in animals fed 25% RMSP. Propionic acid and total volatile fatty acid (TVFA) followed the same trend of variation as observed in acetic acid. Final lactic acid and its variation values observed in this study ranged from 83.00 to 186.50 mmol/100mL and -97.50 to -3.00 mmol/100mL, respectively.

Table 7: Interactive effect of processing methods and malted sorghum sprouts inclusion levels rumen environmental parameters of West African Dwarf goats

Parameters	RMSP			FMSP			
	0%	25%	50%	0%	25%	50%	SEM±
Ph							
Onset	5.17^{a}	4.80^{b}	5.15^{a}	5.17^{a}	4.65^{b}	5.20^{a}	0.06
Final	5.13^{a}	4.96^{ab}	4.55^{c}	5.13^{a}	5.06^{ab}	4.81^{b}	0.08
Variation	-0.04^{b}	0.16^{ab}	-0.60^{c}	-0.04^{b}	0.41^{a}	-0.40^{c}	0.11
NH_3-N (mg/100mL)							
Onset	5.19^{c}	6.04^{b}	6.58^{a}	5.19^{c}	6.70^{a}	6.74^{a}	0.11
Final	6.32^{c}	7.03^{b}	7.45^{a}	6.32^{c}	7.20^{ab}	7.28^{ab}	0.10
Variation	1.14^{a}	0.99^{a}	0.88^{ab}	1.14^{a}	0.50^{b}	0.54^{b}	0.13
Acetic acid (mmol/100mL)							
Onset	134.50^{a}	121.25^{a}	140.25^{a}	134.50^{a}	139.75^{a}	74.00^{b}	14.13
Final	94.13^{b}	54.25^{d}	74.00^{c}	94.13^{b}	125.75^{a}	55.50^{d}	4.13
Variation	-40.38^{ab}	-67.00^{b}	-66.25^{b}	-40.38^{ab}	-14.38^{a}	-18.50^{a}	14.54
Butyric acid (mmol/100mL)							
Onset	44.19^{a}	36.18^{ab}	41.25^{a}	33.88^{ab}	41.18^{a}	21.60^{b}	5.00
Final	78.93^{a}	32.00^{b}	32.30^{b}	32.30^{b}	48.14^{b}	32.43^{b}	8.12
Variation	34.74^{a}	-4.18^{b}	-8.95^{b}	-1.58^{b}	6.96^{b}	10.83^{b}	7.98
Propionic (mmol/100mL)							
Onset	89.50^{a}	80.75^{a}	92.75^{a}	89.50^{a}	93.25^{a}	49.00^{b}	9.36
Final	63.75^{b}	42.50^{d}	54.00^{c}	63.75^{b}	85.00^{a}	37.50^{d}	2.23
Variation	-25.75	-38.25	-38.75	-25.75	-8.25	-11.50	9.35
TVFA (mmol/100mL)							
Onset	359.51^{a}	324.55^{a}	327.25^{a}	359.51^{a}	374.93^{a}	198.00^{b}	37.67
Final	255.67^{b}	158.70^{d}	209.10^{c}	255.69^{b}	343.03^{a}	148.57^{d}	10.18
Variation	-103.85^{ab}	-165.85^{b}	-166.15^{b}	-103.85^{ab}	-31.90^{a}	-49.44^{ab}	38.83
Lactic acid(mmol/100mL)							
Onset	146.50^{ab}	180.50^{ab}	208.75^{a}	146.50^{ab}	200.75^{a}	109.50^{b}	27.80
Final	143.50^{b}	83.00^{c}	93.50^{c}	143.50^{b}	186.50^{a}	83.00^{c}	12.90
Variation	-3.00^{a}	-97.50^{ab}	-115.25^{b}	-3.00^{a}	-14.25^{a}	-26.50^{ab}	30.22

^{abc}Means with different superscripts along the same row are significantly different ($P< 0.05$).
TVFA: Total Volatile Fatty Acids NH_3 –N: Ruminal Ammonia Concentration

Table 8 shows the main effect of processing methods and MSP inclusion levels on the total microbial count in the rumen of WAD goat. This result revealed that processing of malted sorghum sprouts did not indicate any significant ($p>0.05$) difference on the Total Coliform Count (TCC), Total Fungi Count (TFC) and Protozoan except the Total Bacteria Count (TBC). There was a progressive and significant ($p<0.05$) increase in TBC at the end of the experiment. Animals fed diet containing FMSP recorded higher value (0.66×10^6cfu/mL) than those fed diet containing RMSP (0.36×10^6cfu/mL).

However, the main effect of MSP inclusion level showed significant ($p<0.05$) difference on all the parameters observed. At the end of the experiment, values of all the parameters observed increased across the treatment groups as inclusion of MSP increased except the population of protozoan. TBC observed in this study ranged from $5.86\text{-}6.10 \times 10^6$ cfu/mL at the start of the experiment and $5.98\text{-}7.26 \times 10^6$ cfu/mL at the end of the experiment. Animals offered diet containing 50% MSP inclusion recorded higher value ($p<0.05$) than those fed on 0% MSP and 25% MSP inclusions which had similar ($p>0.05$) variation values in TBC. Final TCC were significantly influenced across the dietary treatments. Animals offered diet containing 50% MSP recorded the highest value compared to other dietary treatments. TFC values observed in this study decreased significantly ($p<0.05$) from the commencement to the end of the experiment except those on diet containing 50% MSP inclusion. However, the final TFC values observed increased significantly ($p<0.05$) across the groups as the inclusion level of MSP increased in which animals that consumed diet containing 50% MSP significantly ($p<0.05$) exhibited the highest value (0.66×10^6 cfu/mL) followed by those offered diet containing 25% MSP (0.48×10^6 cfu/mL) and 0% MSP (0.39×10^6 cfu/mL) which had similar values ($p>0.05$). More so, goats fed diet containing 50% MSP recorded the highest value. The protozoan population values observed in this study ranged from 3.38-5.50 mL/100mL at the start of the experiment and 3.75-4.75 mL/100mL at the end of the experiment. The value observed decreased significantly ($p<0.05$) from the onset to the end of the feeding trial except those fed diet containing 0% MSP inclusion level and also decreased significantly ($p<0.05$) across the dietary treatments. Animals fed diet containing 0% MSP recorded the highest final protozoan population and variation values.

Table 8: Main effect of processing methods and malted sorghum sprouts inclusion levels on the total microbial count in the rumen of West African Dwarf goats

Parameters	Processing			Level of MSP inclusion			
	RMSP	FMSP	SEM±	0%	25%	50%	SEM±
TBC (× 10^6cfu/mL)							
Onset	6.00	5.92	0.12	5.91	6.10	5.86	0.14
Final	6.36	6.58	0.08	5.98[b]	6.18[b]	7.26[a]	0.10
Variation	0.36[b]	0.66[a]	0.07	0.06[b]	0.08[b]	1.40[a]	0.82
TCC (× 10^6cfu/mL)							
Onset	0.89	0.93	0.06	0.84	0.89	1.00	0.07
Final	0.53	0.48	0.03	0.41[b]	0.44[b]	0.66[a]	0.41
Variation	-0.36	-0.45	0.07	-0.43	-0.45	-0.34	0.08
TFC (× 10^6cfu/mL)							
Onset	0.60	0.64	0.03	0.58[b]	0.69[a]	0.60[ab]	0.04
Final	0.55	0.47	0.44	0.39[b]	0.48[b]	0.66[a]	0.05
Variation	-0.05	-0.17	0.05	-0.19[b]	-0.21[b]	0.06[a]	0.06
Protozoan(ml/100mL)							
Onset	4.63	4.96	0.19	3.38[b]	5.50[a]	5.50[a]	0.23
Final	4.25	4.17	0.23	4.75[a]	4.13[ab]	3.75[b]	0.28
Variation	-0.38	0.79	0.27	1.38[a]	-1.38[b]	-1.75[b]	0.34

[ab]Means with different superscripts along the same row are significantly different (P< 0.05)
TBC: Total Bacteria Count, TCC: Total Coliform Count, TFC: Total Fungi Count, RMSP: Raw Malted Sorghum Sprouts, FMSP: Fermented Malted Sorghum Sprouts

Table 9 presents the interaction between processing methods and MSP inclusion levels on the total microbial count in the rumen of West African Dwarf goats. All the parameters observed showed significant effect (p<0.05) except the final protozoan values. At the commencement of the trial, Total bacteria count (TBC) ranged from 5.70-6.15 x 10^6cfu/mL while at the end; it ranged from 5.68-7.10 x 10^6cfu/mL. There was a slight increase in the TBC values observed in this study from the initial values to the final values except those animals on diet containing 25% RMSP. TBC and its variation values of animals on diet containing 50% RMSP and 50% FMSP were similar (p>0.05); they were however higher (p<0.05) than those that consume 25% FMSP. Likewise, goats fed diet containing 25% FMSP had higher TBC values (p< 0.05) than those offered 0% MSP, 25% RMSP which were significantly similar (p>0.05). Total coli form count (TCC) values observed in this study ranged from 0.84-1.03 x 10^6cfu/mL at the start of the experiment. Decrement was observed in TCC value from the initial value to the final values observed. Final TCC values observed on goats offered diet containing 50% RMSP recorded the highest value while the lowest was observed on animals fed diet containing 25% RMSP. TFC values followed the same trend of variation as observed in TCC values. Final protozoan value showed no significant effect (p>0.05) across the treatment groups. Animals fed diets containing 0% RMSP and 0% FMSP recorded the highest variation value while those fed diet containing 25% FMSP had the lowest value.

Table 9: Interactive effect of processing methods and malted sorghum sprouts inclusion levels on the total microbial count in the rumen of West African Dwarf goats

Parameters	RMSP			FMSP			
	0%	25%	50%	0%	25%	50%	SEM±
TBC (× 10^6cfu/mL)							
Onset	5.19	6.05	6.03	5.19	6.15	5.70	0.20
Final	5.98^c	5.68^c	7.43^a	5.98^c	6.68^b	7.10^a	0.13
Variation	0.79^b	-0.38^d	1.40^a	0.79^b	0.53^c	1.40^a	0.12
TCC (× 10^6cfu/mL)							
Onset	0.84	0.85	0.98	0.84	0.93	1.03	0.10
Final	0.41^b	0.43^b	0.75^a	0.41^b	0.45^b	0.58^b	0.06
Variation	-0.43	-0.43	-0.23	-0.43	-0.48	-0.45	0.12
TFC(× 10^6cfu/mL)							
Onset	0.58^b	0.60^b	0.63^b	0.58^b	0.78^a	0.58^b	0.05
Final	0.39^b	0.50^b	0.75^a	0.39^b	0.45^b	0.58^{ab}	0.07
Variation	-0.19^{bc}	-0.10^{abc}	0.13^a	-0.19^{bc}	-0.33^c	0.00^{ab}	0.08
Protozoan (mL/100mL)							
Onset	3.38^c	4.50^b	6.00^a	3.38^c	6.50^a	5.00^b	0.32
Final	4.75	4.50	3.50	4.75	3.75	4.00	0.40
Variation	1.38^a	0.00^{ab}	-2.50^c	1.38^a	-2.75^c	-1.00^b	0.47

^{abc}Means with different superscripts along the same row are significantly different (P< 0.05)
TBC: Total Bacteria Count, TCC: Total Coli form Count, TFC: Total Fungi Count, RMSP: Raw Malted Sorghum Sprouts. FMSP: Fermented Malted Sorghum Sprouts.

Digestion in the rumen is dependent on the activity of microorganisms. It also requires energy, nitrogen, minerals, and a suitable medium to enable the microbes to perform well (Ranjhan, 2001). The dry matter and ash digestibility varied significantly with the increasing level of MSP irrespective of the processing methods adopted. Dry matter values were lower than the values of 82.87– 93.61% reported by Olatunji *et al*. (2007) for WAD goats fed diets containing yam peels. The low digestibility coefficient of DM observed in this study could be associated with a low rate of nutrients degradation in MSP, possibly as a result of the presence of some anti-nutritional factors (Sodeinde *et al*., 2007). Thus it implies that the ash digestibility coefficient in goats on diets containing 0% MSP and 50% MSP were more effective in improving the utilization of ash than those on 25% MSP.

The single effect of processing methods immensely improved the dry matter and crude protein digestibility, as well as the digestibility values obtained in a diet containing FMSP. Thus this attests to the fact that the diets were better utilized. The results of nutrient digestibility reported in this study were in accordance with the findings reported by AbdelGani *et al*. (2011) that dietary protein protection improved the digestibility coefficient of many nutrients in sheep and lamb rations.

However, the interaction between the processing methods and MSP inclusion level reflected that the apparent nutrient digestibility of all the nutrients varied significantly across the dietary treatments. The dry matter and crude protein digestibility observed in this study increased progressively as the inclusion level of MSP (regardless of the processing method adopted) increased across the dietary treatments. This study contradicts the findings of Aboakye (2004), who reported a decrease in DM digestibility as the Shea nut cake inclusion level increased in the diet of WAD goats. Animals on a diet containing varying levels of FMSP had better DM and CP digestibility values compared to those fed varying levels of RMSP based diet. The improved feed efficiency values in this study could be due to the proportional increase of FMSP based diet on digestibility coefficients of most nutrients and feeding values. The current results could also be attributable to the effect of fermentation on the test ingredients in the experimental diet that may have increased protein availability to rumen microorganisms to speed up the digestion process.

There was a significant effect of MSP inclusion level on nitrogen (N) intake and faecal N-output. Nitrogen (N) intake values observed in this study increased as the MSP inclusion level increased across the dietary treatments. This study contradicts the report of Okoruwa and Adewumi (2010), who found significantly decreased nitrogen intake with an increased level of 70% dried pineapple pulp in diets of WAD sheep. The lower faecal N-output observed in goats on diets containing 25% and 50% MSP compared with those on 0% MSP could mainly be a reflection of MSP that was well utilized. Dietary treatments significantly influenced urinary nitrogen output. The higher values found in goats fed diets containing 25% MSP and 50% MSP when compared with those on 0% MSP could be due to the concentration of ammonia. Hence nitrogen in the rumen depended on the quantity and solubility of the diets fed to the goats. This result is in line with the report of Ahamefule and Udo (2010) that nitrogen excreted in urine would depend on urea recycling and the efficiency of utilization of ammonia produced in the rumen by microbes for microbial protein synthesis. 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, as observed by Okeniyi *et al*. (2010). Nitrogen balance also followed a similar trend as found in nitrogen retention. The higher positive N-balance observed in animals on diets containing 25% and 50% MSP compared with those on 0% MSP demonstrated that the diets were well utilized and efficiently used as fermentable nitrogen sources for microbial growth in the rumen of the goats (Osakwe *et al*., 2003). The N-balance values obtained in this study are not in conformity with the values reported by Okoruwa and Adewumi (2010).

Processing methods adopted had markedly improved the nitrogen utilization of WAD goats fed MSP based diets. Animals fed a diet containing FMSP exhibited better N-intake, N-retention, and N- utilization. This variation observed indicated that the diets were well utilized. The interaction between the processing methods adopted and the MSP inclusion level revealed that the animals fed diet containing 50% FMSP recorded the highest value in nitrogen N-intake, N-retention, and N-utilization. The nitrogen intake values obtained in this study are higher than those (3.04-3.19 g/animal/day) reported by Ajayi *et al*. (2005) for WAD goats fed some other forages as supplements to a basal diet of *P. maximum*. They are, however, comparable to the values reported by Asaolu *et al*. (2010) for WAD goats on *Moringa* and bamboo-supplemented groundnut hay diets. This variation observed may be attributed to dry matter intake levels and nitrogen concentrations of the experimental feedstuffs. The faecal N-output values obtained in this study decreased as the inclusion level of MSP increased across the dietary treatments in which goats fed diets containing 50% FMSP exhibited the least value while those on 50% RMSP recorded the highest value. It could be attributed to the inhibitory effects of residual toxic and astringent factors associated with RMSP. However, the highest faecal N-output was observed in goats fed diets containing 50% RMSP could primarily be a reflection of MSP that was not well utilized and thus excreted by the goats. Nitrogen retention in g/day and nitrogen balanced were best in goats fed a diet containing 50% FMSP. The highest nitrogen retention and nitrogen balanced values obtained in goats fed this diet probably indicate that the protein requirements for maintenance were adequately met by the diets (Fadiyimu *et al*., 2010). This observation further buttressed the fact that the diet was well balanced in energy and protein, which reduced nitrogen excretion in urine (Noblet and Van Milgen, 2004). The percentage of nitrogen retention values recorded in this study was higher than the values (14.87 to 57.24%) reported by Ajayi *et al*. (2005) for WAD goats that were similar in body weight.

The rumen environmental parameters of WAD goat observed in this study were significantly influenced by the inclusion levels of MSP irrespective of the processing methods adopted. The dietary treatments significantly influenced the initial and final rumen pH values observed in this study. Several reports by Okoruwa *et al*. (2013) and Ososanya *et al*. (2013) indicated that rumen pH is an essential factor that measures the acidity and alkalinity of rumen contents. Thus, for optimum rumen microbial fermentation, rumen pH above 5.8 is helpful to prevent rumen disorders (Zebeli *et al.,* 2008). The decrease observed in final rumen pH across the dietary treatment might be as a result of the high accumulation of the volatile fatty acids (VFAs) in the rumen. VFAs referred to universal end–product of fermentable carbohydrates in the rumen under anaerobic condition contributing about 70% of the ruminant’s energy requirement and the proportion of significant partials of volatile fatty acid concentration in the rumen depends mainly on the type of feed consumed by the animals (Dung *et al.*, 2011).

According to Yusuf *et al.* (2013), if the VFAs production rate exceeds the clearance rate, VFAs will accumulate in the rumen; this may lower the rumen pH and cause the metabolic disturbance known as rumen acidosis. The initial and final rumen ammonia nitrogen (NH_3-N) concentration values obtained fell within the range of values reported by Yusuf *et al*. (2013). The result obtained indicated that rumen NH_3-N concentration had an excellent profile values between 2 and 5 mg/100mL as a minimum rumen fluid for maximum rumen microbial synthesis, 15mg/100mL rumen fluid for maximum fibre digestion and 20mg/100mL rumen fluid which was required for sufficient voluntary intake of low-quality roughage. Hristov *et al.* (2005) had observed that the concentration of rumen NH_3-N depends on the quality and solubility of protein fed to the animals. This variation obtained in final rumen NH_3-N might be due to the high crude protein content from MSP inclusion levels in the diets which influenced the nitrogen uptake by the rumen microbes. The results obtained in this study contradict the findings of Wanapat *et al*. (2005). They found that the rumen NH_3-N concentration in the rumen fluid was not significantly affected by the increasing level of oil, but tended to increase when supplemented with a high level of urea. The higher acetic acid values obtained at the beginning of the experiment might be because the animals depended only on grazing before the commencement of the investigation. Reduction in the TVFAs values observed in the rumen fluid collected at the end of the feeding trial. The result obtained is in accordance with Getachew *et al*. (2008), who reported lower VFAs production by adding condensed tannins in batch culture of mixed rumen microorganisms. The final acetic acid values obtained decreased across the dietary treatments as the MSP inclusion level increased. This observation could be attributed to concentrates diet given to the animals and also the residual effect of the anti-nutritional factors in the MSP. However, the single effect of processing methods adopted markedly improved the rumen environmental parameters of the WAD goat observed in this study. Animals fed diet containing FMSP based diet recorded better rumen environmental parameters compared to those on RMSP based diet.

The interaction between processing methods and MSP inclusion levels revealed that the final rumen pH values obtained in this study decreased as the inclusion level of MSP increased across dietary treatments in which animals fed a diet containing 0% MSP recorded the highest value which may probably be influenced by the high level of protozoan count in the rumen environment. While the lowest pH value observed in goat fed diet containing 50% MSP might probably be due to high total bacteria count (TBC) population in the rumen, leading to high NH_3-N concentration and accordingly lower total VFAs production that lead to lower degradation rate of diets. However, the rumen pH values obtained in this experiment were low compared to the findings of Okoruwa *et al.* (2013) who fed WAD sheep with mixture of orange and pineapple waste at different ratios. The rumen pH had been reported by Cabritta *et al.* (2006) as a measure of acidity or alkalinity of rumen contents, thus for optimum rumen fermentation and fibre digestion, rumen pH should lie between 6.0 and 6.5.

Microbial yield is significant because it is an index of the amount of microbial protein made available to the goat each day. The inclusion level of MSP irrespective of the processing methods adopted significantly influenced the microbial population in the rumen fluid of the animals. There was a slight increase in the value of TBC obtained in this study from the commencement to the end of the feeding trial. More so, final TBC value observed in this study increased as the MSP inclusion level increased across the dietary treatments in which animals fed a diet containing 50% MSP exhibited the highest value. Bacteria degrade the significant part of the ingested feed in the rumen yielding a high accumulation of VFAs across the dietary treatments, thus enhances microbial growth. This result obtained in this work is comparable to that reported by Isah *et al.* (2013). The bacterial count of ruminal fluid is dependent on rumen NH_3-N concentration and pH value of rumen fluid. Both factors are dependent on the type of diet (Yusuf *et al.*, 2013). The highest rumen bacteria count observed in animals fed diet containing 50% MSP might be responsible for high digestion of more protein and fibre yielding more NH_3–N concentration and total VFAs enhancing microbial activities (Yusuf *et al.*, 2013).

Conclusion

The study reveals that the utilization of malted sorghum sprouts can be improved by fermentation. The inclusion of 50% fermented malted sorghum sprouts in diets of West African Dwarf goats improved the overall rumen ecology, digestibility and nitrogen utilization as indicated by its significant positive effect on total nutrient digestibility.

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References

Abdel-Ghani, A. A., G. M. A. Solouma, A. K. I. AbdElmoty, A. Y. Kassab and E. B. Soliman. 2011. Productive performance and blood metabolıtes as affected by protected protein in sheep. Open J. Anim. Sci., 1: 24-32.

Aboakye, A. E. 2004. Apparent digestibility of shea nut cake-based diets fed to sheep. BSc. (Agric. Tech), Dissertation, University for Development Studies, Tamale, pp: 22-27.

Ahamefule, F. O. and M. D. Udo. 2010. Intake and digestibility of West African Dwarf goats fed raw or processed pigeon pea (*Cajanus cajan*) seed meal based diets. Proc.15th Conf. Anim. Sci. Association of Nigeria. Uni. of Uyo. Nigeria. pp: 626-629.

Ajayi, D. A., J. A. Adeneye. and F. T. Ajayi. 2005. Intake and nutrient utilization of West African Dwarf goats fed mango (*Mangifera indica*), Ficus (*Ficus thionningii*), Gliricidia (*Gliricidia sepium*) foliages and concentrates as supplement to basal diet of guinea grass (*Panicum maximum*). World J. Agric. Sci., 1(2):184 – 189.

AOAC. 2002. Association of Official Analytical Chemist. Official methods of analysis.

Asaolu, V. O., S. M. Odeyinka, O. O. Akinbamijo. and F. G. Sodeinde. 2010. Effects of moringa and bamboo leaves on groundnut hay utilization by West African Dwarf goats. Lives. Res. Rural Develop. 22: 1.

Burns, J. C. 2008. ASAS Centennial Paper: Utilization of pasture and forages by ruminants: a historical perspective. J. Anim. Sci., 86: 3647-3663.

Cabrita , A. A. J., R. J. Dewhurst, J. M. F. Abreu. and A. J. M. 2006. Fonseca evaluation of the effects of synchronising the availability of N and energy on rumen function and production responses of dairy cows—A review. Anim. Res., 55:1-24

Dung, D. D., I. R. Godwin. and I. V. Nolan. 2011. Intake, digestibility and rumen fluid parameters of sheep fed commercial pellets or supplemented with barley grain or freeze – dried barley sproutss or freshly barley sproutss. Proceedings of 35th Annual Conference of Nigeria Society for Anim. Product., University of Abuja, Nigeria, pp: 526 – 528.

Fadiyimu, A. A., J. A. Alokan. and A. N. Fajemisin. 2010. Digestibility, nitrogen balance and haematological profile of West African Dwarf sheep fed dietary levels of *Moringa oleifera* as supplement to *Panicum maximum*. J. Anim. Sci., 6: 634-643.

Fafiolu, A. O., A. V. Jegede, O. O. Oduguwa and M. A. Adebule. 2016. Utilisation of malted sorghum sproutss in the diet of pullet chicks. Pertanika J. Trop. Agric. Sci., 39(1): 17-27.

Fanimo, A. O. and S. O. Akinola. 2006. Response of broiler chicken to raw and processed malted sorghum sprouts. World's Poult Sci. J. XII European Poult. Conf., pp: 10-14.

Getachew, G., W. Pittroff, D. H. Putnam, A. Dandekar, S. Goyal. and E. J. De Peters. 2008. The influence of addition of gallic acid, tannin acid, quebracho tannins to alfalfa hay on in *in vitro* rumen fermentation and microbial protein synthesis. Anim. Feed Sci. Technol.. 140: 144-461.

Hristov, A. N., J. K. Ropp, K. L. Grandeen, S. Abedi, R. P. Etter, A. Melgar. and A. E. Foley. 2005. Effect of carbohydrate source on ammonia utilization in lactating dairy cows. J. Anim. Sci., 83:408–421.

Isah, O. A., S. A. Oguntuyo, R. O. Dawodu, O. O. Diya, M. O. Afolabi. and L. A. Omoniyi. 2013. Feed Utilization, Rumen microbial profile of goats fed different browse plants with *P. purpureum* as Basal Diet. Pacific J. Sci. and Technol., 14(1): 397-405

Jegede, A. V., A. O. Fafiolu, A. O. Oni, O. J. Faleye. and O. O. Oduguwa. 2006. Growth performance, nutrient utilization and carcass characteristics of rabbits fed malted sorghum sprouts based diets. J. Anim. Vet. Adv., 5 (10): 852-854

Lanyansunya, T. P., H. Wang, S. Kariuki, E. Mukisira, S. Abdulrasak, N. Kibitok. and J. Ondiek. 2007. The potential of *Commelina benghalensis* as forage for ruminants. Anim. Feed Sci. and Technol., 144: 185-195.

Membrahtu, O. and S. B. Tenaye, 1997. Analytical methods for feeds, Animal Excrements and Animal Tissues. Nutrition Laboratory Manual, ILRI, Ethiopia. 90pp

Mohammed, N. A., I. E. Mohammed. and E. F. Barbiker. 2011. Nutritional Evaluation of sorghum flour (Sorghum bicolour L. Moench) during processing of injera. International J. Biol. Biom. Agric. Food and Biotechnol. Eng., 5: 99–103.

Njoya, A., D. N. Awa. and J. Chupamom. 2005. The effects of a strategic supplementation and prophilaxis on the reproductive performance of primiparous Fulbe ewes in the semi-arid zone of Cameroon. Small Rumin. Res., 56(1-3): 21-29.

Noblet, R. T. and A. A.Vanmilgen. 2004**.** Small ruminant production and the small Ruminant Genetic Resource in Tropical Africa FAO, Rome, Italy, pp: 231.

Ogbonna, A. C., C. I. Abuajah, E. O. Ide. and U. S. Udofia. 2012. Effect of malting conditions on the nutritional and anti-nutritional factors of sorghum grist. Food Technol., 36(2): 64–72.

Okeniyi, F. A., A. B. J. Aina, C. F. I. Onwuka, and S. O. Sowande. 2010. Nutrient digestibility of urea maize stover – based diets as dry season feed in West African Dwarf goats. Proc. 15th Conf. Animal Science Association of Nigeria. University of Uyo, Nigeria. pp: 663-665.

Okoruwa, M. I. and M. K. Adewumi. 2010. Effect of replacing *Panicum maximum* with dried pineapple pulp on nutrient digestibility and nitrogen balance of West African Dwarf sheep. Nigeria J. Anim. Sci., 32: 108–115.

Okoruwa, M. I., M. K. Adewunmi. and A. A. Njidda. 2013. Nutrient Utilization and growth performance of West African Dwarf goats fed with elephant grass or different proportion of plaintain and mango peels. World J. Agric. Sci., 1(6): 194-202.

Olafadehan, O. A. 2011. Changes in haematological and biochemical diagnostics parameters of Red Sokoto goats fed tannin-rich *Pterocarpus enrinaceus* forage diets. Veterinarski Arhiv., 81(4): 471-483

Olatunji, J. E. N., O. M. Arigbede, A. O. Oyebanjo. and O. M. Ajayi. 2007. Performance of WAD goats fed diets containing yam peels. Proc. 32nd Ann. Conf., Nig. Soc. for Anim. Nigeria. pp: 564 – 566.

Osakwe, I. I., H. Steingass, and W. Drochner. 2003. The feeding value of *Mangifera indica* and its effects on crude protein metabolism and energy partitioning when fed to Djallonke sheep. Trop. J. Anim. Sci., 6(1): 47 –52.

Ososanya, T. O., O. T. Odubola. and A. Shuaib-Rahim. 2013. Intake, nutrient digestibility and rumen ecology of West African Dwarf sheep as influenced by pineapple with orange pulps. International J. Agric. Sci., 3(11): 862-870.

Pranoto, Y., S. Anggrahini. and Z. Efendi. 2013. Effect of natural and *Lactobacillus plantarum* fermentation on *invitro* protein and starch digestibilities of sorghum flours. Food Biosci.,. **2**: 46–52. https://doi.org/10.1016/j.fbio.2013.04.001

Ranjhan, S. K. 2001. Animal nutrition in the tropics, 5th edition.Vikas publishing house PVT Ltd, New Delhi, India. pp: 556-559.

Russell, J. B. 2002. Rumen microbiology and its role in Ruminant Nutrition. 10:96-105.

Saka, A. A., O. S. Sowande, O. A. Oni, O. O. Adewumi, F. O. Ogunleke and O. G. Sodipe. 2016. Performance Evaluation and haematological Parameters of West African Dwarf Goats fed diet containing graded levels of raw and fermented malted sorghum sprouts. Nigerian J. Anim. Sci., (2): 444-457.

Santra, A., A. Saikia. and K.. K. Baruah. 2012. Scope of rumen manipulation using medicinal plants to mitigate methane production. J. Pharrnacog., 3(2): 115-120.

SAS. 2004. User’s Guide: Statistics, version 9.1. SAS institute Inc. Cary, NC, USA.Seattle, Washington. pp: 156-339.

Sodeinde, F. G., V. Asaolu, M. A. Oladipo, J. A. Akinlade, A. O. Ige, S. R. Amao. and J. A. Alalade. 2007. Mineral and Anti-nutritional contents of some forage legumes consumed by small ruminants in the derived savannah of Nigeria. Research J. Agronomy. 1(1): 30-32.

Van soest, P. J., J. B. Robertson. and B. A. Levis. 1991. Method for dietary fiber, neutral detergent fibre and non-starch polysaccharides in relation to Animal Nutrition. J. Diary Sci., 74: 3583-3597.

Waghorn, G. 2008. Beneficial and detrimental effects of dietary condensed tannins for sustainable sheep and goat production-Progress and challenges. Anim. Feed Sci. and Technol., 147: 116-139.

Wanapat, M., A. Petlum. and S. Chanthai. 2005. Effects of levels of urea and coconut oil on rumen ecology, milk yield and composition in lactating dairy cows fed on urea-treated rice straw. http://www.mekara.org/proctu/wana13.htm Washington DC.

Yusuf, K. O., O. A. Isah, C. F. I. Onwuka, J. A. Olanite, A. O. Oni. and R. Y. Aderinboye. 2013. Effects of enzymes additive on nutrient intake digestibility and rumen metabolites of yearling cattle fed grass hay-based diet. Nigerian J. Anim. Sci., 15: 155 – 167

Yusuf, A. O., V. Mlambo. and S. O. Iposu. 2018. A nutritional and economic evaluation of *Moringa oleifera* leaf meal as a dietary supplement in West African Dwarf goats. South African J. Anim. Sci., 48(1): 81–87.

Zebeli, Q., M. Dijkstra, H. Tafaj, B. Steigass, N. Ametaj. and W. Drochner. 2008. Modeling the adequacy of Dietary fibre in Dairy Cows based on the responses of Ruminal pH and Milk fat Production to Composition of the Diet. J. Dairy Sci., 91: 2046-2066.