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Performance, digestibility and rumen fermentation characteristics of goats fed leaf meals of *Vernonia amygdalina* or *Moringa oleifera*

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ABSTRACT. A 84-day trial was conducted to investigate the potentialities of *Vernonia amygdalina* and *Moringa oleifera* leaves as natural growth promoters in ruminant production. Hence, the leaves were identified, collected, screened, air-dried, and milled separately into powdery form to make the leaf meals. A basal concentrate diet (BCD - control diet) was formulated, and were divided into nine equal portions while the leaf meals: *V. amygdalina* leaf meal (VALM) or *M. oleifera* leaf meal (MOLM) were added and thoroughly mixed with concentrate diet at 0, 5, 10, 15 and 20 w w^{-1}, per each leaf meal, respectively. Thereafter fed to forty-five West African Dwarf growing goats, randomly allocated to the diets. Nutrient intake, digestibility, rumen fermentation, and weight change of goats were used as response criteria. The results revealed that 20% VALM improved ($p < 0.05$) crude protein intake, nitrogen retention, final live-weight, average daily weight gain (ADWG), and feed conversion ratio. VALM affected rumen fermentation ($p < 0.05$) increasing propionic, butyric acids and total volatile fatty acids (TVFA) concentrations, and total viables bacterial. Further, positive strong correlation ($R^2 = 0.9498$) existed between ADWG and TVFA. It can be concluded that VALM and MOLM are potential phytogenic plants capable of altering the rumen ecosystem for improved nutrient intake, digestibility, rumen fermentation, better than the control diet, without any detrimental effects on growing goats' performance. Summarily, dietary inclusion of VALM at 20% improved feed utilization and animal performance.

Keywords: natural growth promoters; nutrient bio-availability; rumen microbes; tropical leaves.

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Introduction

Ruminant production, especially goats, has the capacity to improve the food and nutrition securities, most importantly in the developing countries like Nigeria. Goat meat is a valuable part of man's balanced diet and is a readily acceptable meat by human beings across the globe. Goat meat is a lean meat and has lower fat than chicken and higher protein than beef. The meat has omega 3 fatty acids, selenium and chlorine which are beneficial to prevent cancer (Lima et al., 2017). These animals depend largely on plant materials due to their stomach's nature but at the same time, there are attendant problems of high cost of production due to seasonal fluctuation of quality and quantity forages. Consequently, this result in poor performance of the animals and diseased conditions. Hence, ruminant farmers often result to the use of antibiotics to boost the general wellbeing of these animals. These are not unconnected with the assertions that the applications of antibiotics and ionophores to boost growth could be toxic and too much dietary fat and cholesterol are not beneficial, as this adversely affects the consumers because of the residual effects of the drugs, if appropriate withdrawal period is not observed.

However, research on the possible ways through the use of natural substances which are readily available in plants have been initiated (Onyimonyi, Olabode, & Okeke, 2009) and one of such means is the use of phytogenic compounds capable of altering the ruminal ecosystem and consequently, could results in improved nutrients intake/absorption and animal' performance. Bitterleaf (*Vernonia amygdalina*) and moringa (*Moringa oleifera*) have been reported to be nutritional and medicinal active (Babiker, Juhaimi, Ghafoor, & Abdoun, 2017) and at the same time contain some bio-active compounds to act as anti-bacterial (Dewangan et al., 2010). Leaves from *M. oleifera* are a low-cost protein supplement compared to other conventional protein supplements (Kholif et al., 2015). The leaf has been reported to contain 90.70% DM, 27% CP, 12% CF, 3.2% EE, 10% Ash, 2.32% Ca and 0.3% P (Abdel-Raheem & Hassan, 2021). Similarly, *V. amygdalina* are rich source of protein, crude fibre and mineral content. However, contains some negligible amount of anti-nutritive compounds such as tannin, terpenoid which inhibits activities of methanogens (Beauchemin, McGinn, Martinez, & McAllister, 2007) and has an astringent taste. According to Aregheore, Makkar, and Becker (1998), bitterleaf was reported to contain 20-34% (CP) with about 200 species and can be used as an antioxidant, anti-diarrhoea, growth promoter and for medicinal purposes (Cieslak, Szumacher-Strabel, Stochmal, & Oleszek, 2013). With these attributes of *M. oleifera* and *V. amygdalina*, it is believed that the leaves would be capable of influencing the ruminal ecosystem, methane production, and consequently improved animal' performance. Therefore, *Vernonia amygdalina* and *Moringa oleifera* are multipurpose, drought-resistance, and tropical plants that could be harnessed for their inherent potentials to modulate the rumen microbes for improved animal performance. Hence, his study concerned itself with the effects of *Vernonia amygdalina* and *Moringa oleifera* leaf meal in growing goats' nutrition with a view to assessing the animal' performance using nutrient digestibility, ruminal fermentation and weight gain as response criteria.

Material and methods

Experimental site

The field trial was conducted in the Small Ruminant Unit of the Teaching and Research Farm while Laboratory analyses were done at the Microbiology and Nutrition Laboratory of the Department of Animal Production and Health, Federal University of Technology, Akure (FUTA), Nigeria, consequent upon the approval by the Research and Ethics Committee, Department of Animal Production and Health, FUTA with reference number - FUTA/APH/2021/02. The University is geographically located in the humid rain forest zone of Western Nigeria, within the coordinates 7º 10' N 5º 12' E.

Sourcing and processing of feed ingredients

The Department of Crop, Soil and Pest Management, Federal University of Technology, Akure (FUTA) identified the leaves (*Vernonia amygdalina* and *Moringa oleifera*), that were collected at the Teaching and Research Farm, air-dried, grounded (Figure 1a and b) and stored in air-tight hygenically cleaned plastic for later use. Other conventional feed ingredients were procured at a reputable feed mill industry in Akure while fresh cassava peels were collected at cassava processing industries in Akure, sun-dried to a stable weight to reduce the hydro-cyanide and facilitate milling and mixing with other feedstuffs.

Experimental diets

A basal concentrate diet (control diet) was formulated using cassava peel, wheat offal, brewer dried grain, palm kernel cake, urea-molasses and other micronutrients (Table 1) to meet nutrient requirements for growth of growing goats as recommended by National Research Council (NRC, 2007). While the leaf meals: *V. amygdalina* leaf meal (VALM) or *M. oleifera* leaf meal (MOLM) were thoroughly mixed with concentrate diet (concentrate : leaf meal) at 5, 10, 15 and 20 w w^{-1}, per each leaf meal, to make nine (9).

Figure 1. a) *M. oleifera* leaf meal; b) *V. amygdalina* leaf meal.

Table 1. Basal concentrate diet - control diet.

Ingredient	Quantity (%)	*V. amygdalina*	*M. oleifera*
Cassava peel meal	55.00	-	-
Wheat offal	20.00	-	-
Brewer's dried grain	14.00	-	-
Palm kernel cake	7.00	-	-
Urea-molasses	1.00	-	-
*Other micronutrients	3.00	-	-
Total	100.00	-	-
Chemical composition, %			
Dry matter	89.67	86.98	88.21
CP	17.22	26.10	22.86
Crude fibre	8.37	7.20	8.58
NDF	53.57	52.81	60.34
ADF	34.02	33.77	32.88
ADL	18.76	16.67	27.98

*Other micronutrients are salt, vitamin-mineral premix, bone meal.

Management of experimental goats and data collection

Forty-five West African Dwarf (WAD) breed of growing goats, with an average bodyweight of 8.01 kg and age range 12 - 18 months, were used for this trial. Before the commencement of trial, the goats were prophylactically treated against endo- and ecto-parasite using Ivermectin at 1 mL per 10 kg b.w. of animal subcutaneously and drenched with Albendazole®. The goats were vaccinated against Pesté-Petit dé Ruminanté using tissue culture rinderpest vaccine at 1 mL per 10 kg body weight.

The goats were allocated to the diets at five goats per treatment, balanced for weight, arranged in a completely randomized design experiment. The goats were housed in individual pen and an adjustment period of 7 days were allowed prior to collection of data. The goats were offered the diets at 5% of their body weight at 8:00 am and potable water were given throughout the growth trial which lasted eighty-four (84) days. The day-by-day feed consumption become decided through subtracting the leftovers from the amount served. Weekly weight change of each goat was monitored by weighing the animals in the morning hours after overnight fasting (before feeding), using hanging weighing scale (Salter model) having 100 g calibration. Average daily weight gain was calculated as the difference between final weight and initial weight divided by the number of experimental days.

Digestibility trial

This phase of the trial was done after the termination of growth trial, by moving the goats to the metabolism cages, housed individually for feacal and urine sample collection, two weeks before the termination of the feeding trial. The first 7 days was for the goats to adjust to the cage, while samples were collected for 7 days. Daily total faeces and urine voided were collected, measured, and recorded in the morning. The urine collected using a plague bucket placed under each cage to which 2-3 drops of 25% H_2SO_4 was added to prevent ammonia escape from the urine.

10% of faeces and urine collected from each animal stored and sub-samples were bulked for appropriate analysis. Apparent nutrient digestibility of the diets were estimated as difference between nutrients intake and excretion in the faeces, expressed as a percentage of nutrient intake. Percentage nitrogen retention by the goats were deduced as the difference between nitrogen intake and nitrogen excreted, expressed as a percentage of nitrogen intake.

Ruminal fermentation characteristics trial

Rumen liquor (about 30 - 40 mL) were collected from each goats using a suction tube 3 hours post-feeding in the morning, at the end of the digestibility trial. Digitized pH meter was used to read the rumen pH immediately after collection. The samples of rumen liquor were filtered through a one layer of cheesecloth, to get rid of sediments, and 2 mL rumen liquor samples were diluted in 4 mL of methyl green-formalin-saline solution, stored in glass bottles in a dark place at room temperature, and counted the protozoa (Elghandour et al., 2017).

For volatile fatty acids (VFA) determination, a portion of the filtered rumen samples was thawed at 4°C and analyzed using high-performance liquid chromatography (HPLC). The filtrate was acidified with 5% tetra-oxo-sulphate (vi) acid (H_2SO_4) solution and left to rest for 30 min. After centrifugation, the liquid was decanted and titrated with sodium hydroxide (NaOH) using phenophalin as an indicator. Acetic acid, propionic acid, and butyric acid standards were prepared, and a wavelength of 210 nm was used. The titre values obtained were used to determine the concentration of volatile fatty acids (Association of Official Analytical Chemists [AOAC], 2011). Another portion of the filtered rumen samples was centrifuged, and the supernatant was collected for ammonia content determination (Parsons, Maita, & Lalli, 1984). The rumen ammonia nitrogen (NH_3-N) concentration was measured using the method of AOAC (2011).

Determination of rumen microbiota

The plate count method was used to calculate the total bacteria count, and total anaerobic bacteria count. A portion of each goat's rumen liquor was tested for the presence of bacteria, fungi, and coliforms. The pour plate technique was used to obtain colony-forming units per milliliter (cfu mL^{-1}) of bacteria and fungi. The culture media were nutrient agar and potato dextrose agar. The majority of ruminal bacterial species were grown on relatively simple media containing carbohydrates (such as cellulose, starch, and glucose), ammonia, trypticase, B-vitamins, heme, vitamin K derivatives, mineral salts, and a reducing agent such as sodium sulfide and L-cysteine. The plates were incubated at 37°C for 24 hours, and all visible colonies were present at the end of the incubation.

Laboratory analysis

Sub-samples of experimental diets, faeces and urine were bulked for chemical/nutrient analyses, while urine samples were analysed for nitrogen according to AOAC (2011) procedures. Crude protein was computed as nitrogen, N multiplied by the conversion factor value of 6.25 while the fibre fractions were determined using the method of Van Soest, Robertson, and Lewis (1991).

Experimental design and statistical analysis

Completely randomized design was used, with the model: Yij = µ + ai + ith + eij. Where Yij is the response variable; µ - the population mean; ai - dietary effect of the leaf meals, ith treatment (i = inclusion levels of leaf meals - dietary treatment 1, 2, 3, 4, 5, 6, 7, 8 and 9); eij - experimental error. Data generated were subjected to statistically analysis using one-way analysis of variance (ANOVA) using Statistical Package for the Social Sciences (SPSS, 2011) version 23.0. The treatment means were separated using Duncan Multiple Range Test (DMRT) of the same package at probability level of 5%.

Results and discussion

The evaluated leaf meals could serve as unconventional protein sources for ruminants as nitrogen contribution from the VALM from 10% of inclusion or MOLM from 15% of inclusion leaf meals improved ($p < 0.05$) the protein content of the formulated basal diet (Table 2). MOLM increased NDF from 15% of inclusion and that VAM reduced lignin (ADL) and thus would encourage nutrients intake, rumination by filling the rumen gut.

The goats fed diets containing 20 g kg^{-1} feed of VALM or MOLM had the best dietary crude protein and crude fibre intake (Table 3). From this study, it was observed that DMI were not influenced by VALM or MOLM, but the higher CP intake by the goats could be traced to the higher nitrogen contribution or CP content of the leaf meals. Further, it was observed that the MOLM inclusion from 10% influenced ($p < 0.05$) NDF and ADL intake, and could be attributed to the age/season at harvest and probable stem to leaf ratio of the Moringa.

Table 2. Nutrient composition of experimental diets.

Parameters (%)	Control	*V. amygdalina* level				*M. oleifera* level				p- value
		5%	10%	15%	20%	5%	10%	15%	20%	
Dry matter	89.67	88.99	88.57	89.01	88.99	88.87	88.56	88.48	88.45	0.61
CP	17.22[c]	17.58[bc]	17.77[b]	17.98[b]	18.21[a]	17.42[bc]	17.59[bc]	17.83[b]	18.00[b]	0.03
Crude fibre	8.37	8.39	8.43	8.47	8.49	8.37	8.41	8.46	8.48	0.52
NDF	53.57[b]	53.04[b]	53.64[b]	53.89[b]	53.97[b]	54.78[b]	55.01[ab]	55.55[a]	55.56[a]	0.03
ADF	34.02	33.33	33.63	33.68	33.87	33.45	33.56	33.59	33.87	0.54
ADL	18.76[a]	17.67[b]	17.67[b]	17.88[b]	17.98[b]	18.43[a]	18.45[a]	18.66[a]	18.69[a]	0.01

abcdef: means on the same row with different superscript are significantly ($p < 0.05$) different. CP - Crude protein, NDF - Neutral detergent fibre; ADF - Acid detergent fibre; ADL - Acid detergent lignin, Control - Formulated basal diet.

Table 3. Nutrient intake (g day^{-1}) by goats fed varying levels of VALM or MOLM diets.

Nutrients	FBD	*V. amygdalina* level - VALM				*M. oleifera* level - MOLM				SEM	p-value
		5	10	15	20	5	10	15	20		
DM	361.2	363.1	367.0	365.1	367.2	361.6	363.2	361.4	367.5	5.17	0.29
CP	69.36^{d}	71.73^{cd}	73.64^{b}	73.75^{b}	75.14^{a}	70.88^{cd}	72.14^{c}	72.83^{c}	74.80^{a}	2.89	0.04
CF	33.71^{c}	34.23^{bc}	34.93^{b}	34.74^{b}	35.03^{a}	34.06^{bc}	34.49^{b}	34.56^{b}	35.24^{a}	1.18	0.01
EE	26.91	26.4	26.85	26.7	26.95	25.72	26.12	26.06	26.72	0.92	0.31
ASH	45.19	45.25	46	45.7	46.13	45.21	45.61	45.5	46.42	0.43	0.29
NFE	227.62^{b}	230.40^{ab}	232.98^{a}	229.30^{ab}	229.39^{ab}	231.04^{a}	231.76^{a}	227.80^{b}	232.38^{a}	4.78	0.02
NDF	215.78^{b}	216.40^{b}	222.28^{b}	221.06^{b}	222.71^{b}	222.90^{b}	225.61^{a}	226.90^{a}	230.88^{a}	14.67	0.01
ADF	137.03	135.99	139.36	138.16	139.76	136.11	137.64	137.2	140.75	2.68	0.47
ADL	75.57^{a}	72.09^{b}	73.22^{b}	73.34^{b}	74.19^{ab}	74.99^{ab}	75.67^{a}	76.22^{a}	77.67^{a}	4.34	0.01

abc: means on the same row with different superscript are significantly ($p < 0.05$) different. DM - Dry matter, CP - Crude protein, EE - Ether extract, NFE - Nitrogen free extract; NDF - Neutral detergent fibre; ADF - Acid detergent fibre; ADL - Acid detergent lignin, VALM - Vernonia amygdalina leaf meal; MOLM - Moringa oleifera leaf meal; FBD - Formulated concentrate diet. NS = Not Significant ($p > 0.05$); * = Significant at $p < 0.05$.

Nitrogen intake, balance and N retention were significantly ($p < 0.05$) influenced (Table 4). It is noteworthy that diets containing 20% VALM had the highest N intake, N balance and N retention than Control diet and was similar compared to diets containing 20% MOLM confirming the protein quality of the VALM and MOLM and bio-availability for growth and development. Hence, it could be said that N utilization has a direct and positive reflection to higher protein and lower fibre content, with respect to 20% VALM and MOLM inclusions. Thus, improved microbial protein synthesis in the rumen (not 'bypass protein'), and nutrients are absorbed at the absorption sites for optimum tissue development (growth).

Apparent nutrient digestibility of a feed function of varying factors such as, feed quality, water intake, rumen ecosystem, among others. This has direct relationship with dry matter digestibility as the extent to which DM will be digested is dependent on the cell wall constituents. From Table 5, the leaf meal improved nutrient digestion by the goats. The increased fibre fraction digestibility in leaf meal supplemented diets is a sign that more glucose was released for goats' better performance. The apparent nutrient digestibility coefficient values observed in this current study is a prove that the diets were properly degraded within the rumen.

Goats placed on the control treatment had the least weight gain compared to animals fed diet containing VALM or MOLM from 15% of inclusion, and is traceable to the supplementation of the leaf meal which contributed additional nutrients/nitrogen to the animals. It was observed that the final live-weight, total weight gain and ADWG were higher ($p < 0.05$) for 20% VALM supplemented diet. This agreed with the reports of Asaolu, Binuomote, Akinlade, Aderinola, and Oyelami (2012) and Ali et al. (2018) that the supplementation of leaf meals improved nutrient composition, intake and weight gain, as goats fed diet containing 20 g VALM kg^{-1} feed had the highest values (12.44 kg, 4.46 kg and 53.1 g d^{-1}). Goats fed control diet had higher ($p < 0.05$) feed conversion ratio than the supplemented treatments (Table 6). The FCR seems to have direct relationship with quality of diets and weight gain, which could be as a result of the leaf meal supplementation once goats fed diet containing 20 g VALM kg^{-1} feed were more efficient in the utilization of nutrients for their live weight gain.

From this current trial, there are indications that the leaf meals in general contributed to the weight gain and performance of the animals by stimulating rumen microbes' activity resulting to improved nutrient digestibility, total volatile fatty acids, and microbial protein production. Further, VALM could be said to have better increased the bacteria population to degrade lingo-cellulosic contents in the rumen and consequently, leading to enhanced in nutrient absorption and utilization. The highest propionic acid, butyric acid and total VFAs in the diets containing highest level of leaf meals indicates the ability of the leaves, especially the VALM, to promote the activities of rumen microbes, which in turn stabilizes rumen pH, decreases rumen lactic acid, and improves nutrient digestibility. Thus, indicates efficiency of nutrient digestion. Supplementation with leaf meal (VALM or MOLM) also supports the production of propionic and total volatile fatty acids. Propionate is the main substrate for glucose in ruminants and gluconeogenesis (Dijkstra et al., 2012). The significantly higher propionic acid concentration observed in this present study could be attributed to the reduced production of CH_4 and CO_2 as opined by Lila et al. (2004), which on the other hand, causes a significant increase in acetic acid production. It is noteworthy that a significant changes in the acetic acid production implies a modification of the rumen ecosystem (microbial population). Thus, the lower acetic acid concentration in goats fed 20 g VALM kg^{-1} feed implied best feed utilization. A positive and linear progression was observed between average daily weight gain and total volatile fatty acid production as a result of the leaf meal supplementation (Figure 2). Hence, a very strong and positive linear correlation ($R^2 = 0.9498$) existed among these variables and this implies efficient nutrient bio-availability, feed utilization and absorption, and consequently, responsible for the better performance in goats fed diet containing 20 g VALM kg^{-1} feed.

Table 4. Nitrogen utilization (g day^{-1}) by goats fed varying levels of VALM or MOLM diets.

Nutrients	FBD	*V. amygdalina* level - VALM				*M. oleifera* level - MOLM				SEM	p-value
		5	10	15	20	5	10	15	20		
N intake	11.10^{b}	11.48^{ab}	11.78^{ab}	11.80^{ab}	12.02^{a}	11.34^{ab}	11.54^{ab}	11.65^{ab}	11.97^{ab}	0.57	0.01
Faecal N	0.73^{ab}	0.79^{a}	0.66^{b}	0.59^{bc}	0.57^{bc}	0.47^{c}	0.66^{b}	0.68^{b}	0.57^{bc}	0.31	0.00
Urinary N	0.24^{b}	0.30^{a}	0.15^{c}	0.30^{a}	0.14^{c}	0.23^{b}	0.17^{c}	0.26^{b}	0.19^{bc}	0.09	0.01
N balance	10.13^{c}	10.39^{c}	10.97^{b}	10.91^{b}	11.31^{a}	10.64^{b}	10.71^{b}	10.71^{b}	11.21^{a}	1.05	0.02
N ret., %	91.26^{b}	90.50^{c}	93.13^{ab}	92.46^{ab}	94.09^{a}	93.83^{a}	92.81^{ab}	91.93^{b}	93.65^{a}	3.01	0.04

abc: means on the same row with different superscript are significantly ($p < 0.05$) different. N - Nitrogen, VALM - Vernonia amygdalina leaf meal; MOLM - Moringa oleifera leaf meal; FBD - Formulated concentrate diet. NS = Not Significant ($p > 0.05$); * = Significant at $p < 0.05$.

Table 5. Apparent nutrient digestibility (%) by goats fed varying levels of VALM or MOLM diets.

Nutrients	FBD	*V. amygdalina* level - VALM				MOLM				SEM	p-value
		5	10	15	20	5	10	15	20		
DM	89.06^{a}	88.67^{a}	87.21^{ab}	86.67^{b}	89.35^{a}	87.23^{ab}	87.76^{ab}	86.25^{b}	85.78^{b}	1.12	0.03
CP	91.26^{b}	90.50^{b}	93.13^{a}	92.46^{ab}	94.09^{a}	93.83^{a}	92.81^{ab}	91.93^{b}	93.65^{a}	2.89	0.01
CF	77.75^{c}	84.02^{b}	85.17^{b}	85.63^{b}	88.93^{a}	78.72^{c}	78.42^{c}	78.09^{c}	76.98^{c}	4.78	0.02
EE	75.23^{b}	77.93^{b}	79.61^{a}	79.87^{a}	80.15^{a}	72.98^{c}	73.42^{c}	74.89^{b}	75.90^{b}	1.12	0.02
NFE	72.13^{c}	75.14^{bc}	75.53^{bc}	76.98^{b}	79.67^{a}	76.02^{b}	76.11^{b}	77.78^{b}	77.51^{b}	0.48	0.01
NDF	58.48^{c}	64.19^{c}	64.32^{c}	67.67^{b}	68.57^{b}	70.91^{b}	73.41^{b}	75.15^{a}	76.58^{a}	2.56	0.00
ADF	73.42^{b}	74.56^{ab}	75.00^{ab}	75.30^{ab}	76.03^{ab}	77.23^{a}	76.39^{a}	75.90^{ab}	75.77^{ab}	1.1	0.04
ADL	55.09^{c}	59.41^{c}	62.03^{b}	63.47^{b}	66.19^{b}	71.76^{ab}	75.97^{a}	77.88^{a}	72.38^{ab}	1.27	0.01

abc: means on the same row with different superscript are significantly ($p < 0.05$) different. DM - Dry matter, CP - Crude protein, EE - Ether extract, NFE - Nitrogen free extract; NDF - Neutral detergent fibre; ADF - Acid detergent fibre; ADL - Acid detergent lignin, VALM - Vernonia amygdalina leaf meal; MOLM - Moringa oleifera leaf meal; FBD - Formulated concentrate diet. NS = Not Significant ($p > 0.05$); * = Significant at $p < 0.05$.

Table 6. Growth rate of goats fed varying levels of VALM or MOLM diets.

Parameters	FBD	*V. amygdalina* level - VALM				*M. oleifera* level - MOLM				SEM	p-value
		5	10	15	20	5	10	15	20		
Initial wt. kg	8.01	8.04	8.04	7.99	7.99	8.00	8.01	8.03	8.02	0.54	1.00
Final wt. kg	10.27^{d}	10.51^{c}	10.73^{c}	11.31^{bc}	12.44^{a}	10.38^{d}	10.79^{c}	11.03^{bc}	11.81^{b}	1.19	0.03
Wt gain, kg	2.26^{d}	2.47^{d}	2.69^{cd}	3.32^{c}	4.46^{a}	2.38^{d}	2.78^{cd}	3.00^{c}	3.79^{b}	1.51	0.01
ADWG, g/d	26.90^{e}	29.40^{de}	32.02^{d}	39.52^{c}	53.10^{a}	28.33^{de}	33.10^{d}	35.71^{d}	45.12^{b}	21.46	0.02
FCR	13.42^{a}	12.35^{b}	11.46^{bc}	9.24^{c}	6.92^{d}	12.76^{b}	10.97^{bc}	10.12^{bc}	8.15^{c}	4.18	0.04

abc: means on the same row with different superscript are significantly ($p < 0.05$) different. ADWG - Average daily weight gain, FCR - Feed conversion ratio, VALM - Vernonia amygdalina leaf meal; MOLM - Moringa oleifera leaf meal; FBD - Formulated concentrate diet. NS = Not Significant ($p > 0.05$); * = Significant at $p < 0.05$.

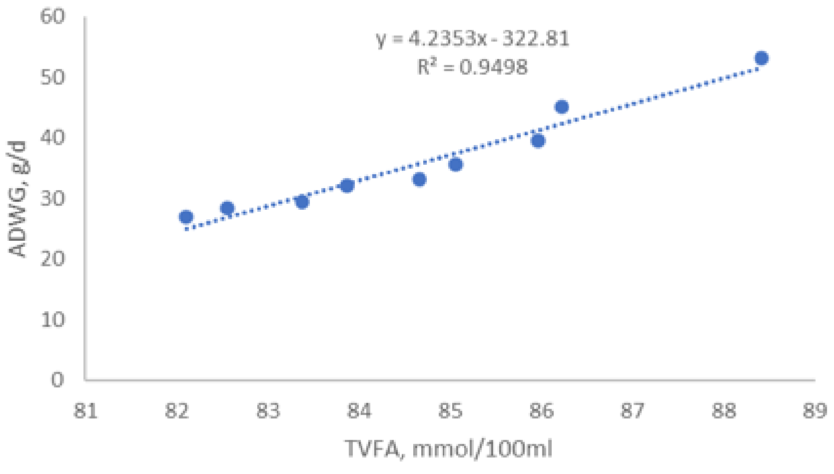

Figure 2. Relationship among average daily weight gain and total volatile fatty acid production.

Volatile fatty acids (VFAs) are the end-product of carbohydrate metabolism; and energy sources to ruminant animals but also influence methanogens. The amount of total VFA produced is a function of nutrient composition, nutrient bioavailability, nutrient' absorption rate, rate of passage rate in the stomache, ruminal pH, nutrient digestibility, and population and activities of rumen microbes (Zenobi, Lardner, Jefferson, & McKinnon, 2015). From Table 7, the total VFA recorded in this present study were in agreement with the values (80.74 - 85.42 mmole L^{-1}) for buffalo calves (Abdel-Raheem & Hassan, 2021) but slightly higher than the values reported by Chanjula, Petcharat, and Cherdthong (2018) when they studied the effect of biologically treated palm oil fronds on the rumen fermentation and feed utilization by goats. Accordingly, the production of both VFA and lactic acid is a function of the rate at which water-soluble carbohydrate in the diet is utilized. The liver absorbs partially the acetic acid and oxidized it to generate adenosine-triphosphate. Hence, becomes the primary source of acetyl CoA for synthesis of lipids. Diets high in roughage results in increased acetate production. Thus, could be responsible for the significantly higher acetic acid production in control diet. Meanwhile, propionic acid production is positive reflection of the dietary protein quality and contributes to growth. This could be attributed to the better performance by goats fed diet with 20 g VALM kg^{-1} feed, as the nutrients were better absorbed at the small intestine for optimum growth. The rumen pH of all the goats in this present study ranged from 5.60 to 6.60; and falls within the reported values by Abdel-Raheem and Hassan (2021) when they assessed the dietary effect of Moringa inclusion in buffalo calves' performance. Hence, values recorded were normal to support the activities of the rumen bacteria for fermentation process and optimum feed (fibre and protein) digestion (Franzolin, Rosales, & Soares, 2010). Production of ammonia nitrogen is speed up through the activities of the rumen microbes to vigorously attack and breakdown the fibre and protein into ammonia (Fliegerova et al., 2021). This is evident as goats fed with 20% VALM) had the highest concentration of ammonia nitrogen, and thus implies that ruminal microbial activities are favoured for adequate digestion of the diet. The leaf meals (VALM and MOLM) are suggestive to have effect on gastro-intestinal tract of the goats by lowering the ruminal protein degradation and decrease rumen ammonia (Jelali & Salem, 2014; Abdel-Raheem & Hassan, 2021).

Table 7. Rumen pH and volatile fatty acids (mmol 100 mL^{-1}) of goats fed varying levels of VALM or MOLM diets.

Parameters	FBD	*V. amygdalina* level - VALM				*M. oleifera* level - MOLM				SEM	p-value
		5	10	15	20	5	10	15	20		
Acetic acid	6.20^{a}	6.15^{bc}	6.13^{bc}	6.07^{d}	6.02^{d}	6.17^{b}	6.13^{bc}	6.14^{bc}	6.19^{ab}	0.11	0.01
Propionic	5.77^{c}	5.89^{b}	5.91^{ab}	5.97^{ab}	6.01^{a}	5.83^{b}	5.92^{ab}	5.99^{a}	6.03^{a}	0.09	0.01
Butyric	5.78	5.80	5.84	5.93	5.96	5.81	5.87	5.91	5.94	0.09	0.17
Valeric acid	6.20^{a}	5.40^{d}	5.50^{c}	5.54^{c}	5.47^{c}	5.86^{b}	5.48^{c}	5.34^{d}	5.20^{e}	0.15	0.01
Lactic acid	8.30^{a}	8.22^{ab}	8.01^{c}	8.11^{b}	7.89^{d}	8.11^{b}	8.23^{ab}	8.12^{b}	8.11^{b}	0.47	0.02
TVFA	82.11^{d}	83.38^{c}	83.88^{c}	85.97^{b}	88.42^{a}	82.56^{d}	84.67^{c}	85.07^{bc}	86.23^{b}	2.23	0.01
pH	5.60^{d}	5.80^{c}	6.20^{b}	6.50^{a}	6.60^{a}	6.00^{b}	5.80^{c}	6.50^{a}	6.50^{a}	1.01	0.01
NH_3N (%)	0.57^{c}	0.58^{c}	0.60^{b}	0.60^{b}	0.61^{a}	0.58^{c}	0.59^{b}	0.59^{b}	0.60^{b}	0.01	0.00

abc: means on the same row with different superscript are significantly ($p < 0.05$) different. TVFA - Total volatile fatty acids, pH - Potential of hydrogen, NH_3N - Ammonia nitrogen, VALM - Vernonia amygdalina leaf meal; MOLM - Moringa oleifera leaf meal; FBD - Formulated concentrate diet. NS = Not Significant ($p > 0.05$); * = Significant at $p < 0.05$.

Microbial protein synthesis is essential for evaluating animal performance, as its production is dependent on the quality of the feed, rumen microbial population (Harun & Sali, 2019), and supplies more than 50% of amino acids needed for growth and development in ruminants. Hence, as shown in Figure 3, the rumen microbial population is ($p < 0.05$) influenced ($p < 0.05$) by the leaf meals supplementation. The total viable bacteria counts were slightly higher than values (1.84 - 2.30 cfu mL^{-1}) x 10^5 reported by Ikyume et al. (2018) when the supplemented West African Dwarf goat diet with varying levels of garlic powder. It is noteworthy that rumen microbiota, according to Millen, Arrigoni, and Pacheco (2016), are essential for maintaining digestive and metabolic functions, provide enzymes necessary for fermentation of diet ingested by ruminants, and also helps to synthesize amino acids and vitamins that are absorbed in the small intestine. Hence, it is suggestive that the *V. amygdalina* and *M. oleifera* leaf could help to reduce enteric methane production viz-a-viz global warming, through defaunation of rumen protozoa while improving feed utilization/animal performance (Beauchemin et al., 2007).

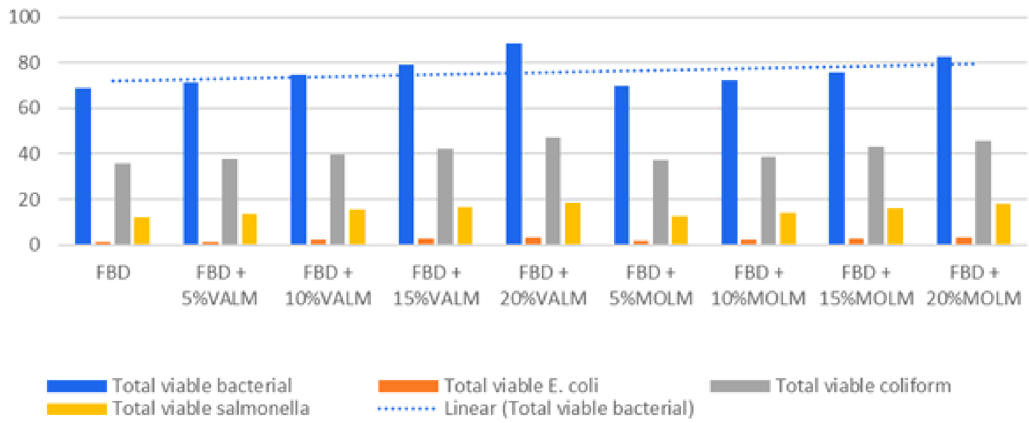

Figure 3. Rumen microbial count (cfu mL^{-1} x10^2) by goats fed varying levels of VALM or MOLM diets.

Conclusion

The leaf meals have impact on nutrient intake, rumen function and nitrogen utilization of goats, digestion coefficients of nutrients. However, Vernonia amygdalina at 20% better improved the animal performance and it is opined that 20% VALM could adequately be used as a protein source and anti-methanogenic plant in goats' rations.

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