Impact of Herb Oils on Digestion, Lipid Profile and Methane Emissions in Goats Fed Mixed Maize/Rice Straw-Hay as Alternative Basal Diets

M. I. Okoruwa

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

Abstract: **The study was conducted to determine the effects of oils on nutrient digestions, lipid profile and methane emissions in goats fed mixed maize/rice straw-hay as alternative basal diets. Garlic, ginger or lemon grass oil as additives was used with 60% mixed maize/rice straw-hay and 40% concentrate supplement to prepare diets. The four compared diets were; 60% mixed maize/rice straw-hay and 40% concentrate diet without oil (MRH_1) and 60% mixed maize/rice straw-hay plus 40% concentrate diet treated with 2mg/g/day of either garlic oil (GAH_2), ginger oil (GIH_3) or lemon grass oil (LEH_4). About 200mg of each of the diets with mixture of medium solution and rumen fluid (2:1) was used for *in-vitro* methane emissions and degradability. Twenty four West African dwarf goats of about 8 to 9 months of age were randomly allocated to the four diets in a completely randomize design. Methane production, neutral detergent fibre degradation, feed conversion, ammonia nitrogen, total volatile fatty acids with cholesterol, acetate, low density lipoprotein, triglycerides, faecal and urinary nitrogen output were significantly ($p<0.05$) higher in MRH_1. Weight gains, propionate, digestibility of nutrients and nitrogen retention were greater in GAH_2, while feed intake and high density lipoprotein were better ($p<0.05$) in LEH_4. Rumen pH, butyrate and ash digestibility were not significant ($p<0.05$) among diets. It can be concluded that effects of oils on mixed maize/rice straw-hay enhanced performance and suppressed methane in goats.**

Keywords: **goats, herb oils, methane, performance, rumen.**

I. INTRODUCTION

Raising of goats is an integral part of livestock production, especially under small holder farming system in the tropics. Goats play multifarious roles in the livelihood of resource challenged farmers living under extreme condition in the society. They also account for essential protein source in the diets of humans and help to provide extra income that supports the survival of many farmers in rural areas [1]. In spite of these benefits, their products are still limited due to slow growth rate that take time to achieve the desired market weight, hence decreasing the overall profitability of livestock sector [2]. Poor animal nutrition among other challenges has been identified as one of the major constraints that bring low productivity in most developing counties. However, ruminants suffer from underfeeding and malnutrition resulting from aggravated high cost of conventional feeds and inadequate utilization of high fibrous feeds particularly during the dry season when forages are scarce [2]. Supply of quality feeds to small ruminants during drought is extremely precarious and the gap is huge against the demand. In this regards, a key to sustainable goat production is efficient use of available feed resources including a reduction in wastage and enlargement of the feed ingredients base through a quest for novel feed resources, particularly those not completing with human in their usage [3]. This necessitates the evaluation of some non-conventional feed resources that are cheaper with good nutritional potential values to alleviate feed deficits.

Goat feeding during off-season depends mainly on fibrous crop-residues that are readily accessible by small to medium scale farmers in most rural areas. Usually cereal straws contain higher ratio of lingo-cellulosic biomass materials with lower amount of protein and digestible organic matter which impede ruminant productivity [4]. Maize and rice straws are such relevant low quality roughages that are highly abundant and widely distributed as low cost feeds which find sustainable ways of relieving goat farmers. There are aggravating facts that high percentage of crop residues are indiscriminately discarded and accumulated as waste in public areas contaminating water and soil resources, which may lead to a consequent increase in disease vectors for humans. In line with this trend, negotiations are employed to use much of these by-products as alternative feeds to natural pastures during feed shortage to minimize environmental hazard, pollution and incorrect soil incorporation. However, their degradation in the rumen due to high fibre content is difficult and associated with methane gas [5]. Methane emission poses a great challenge to environmental sustainability being the major contributor to greenhouse gas and loss of carbon sources culminating to unproductive dietary energy use with considerable loss of up to 12% dietary energy intake [6]. Thus, some researchers had evaluated the potential of incorporating additives into crop-residues as one way of regulating methane losses and adding value to improve their utilisation for better performance in ruminants [7]. Though, several factors including processing methods, diet composition and inclusion levels of additive may affect their utilization in animals.

Feed additives are included in livestock diets to improve feed conversion and product quality. The use of commercial feed additives in animal diets are rapidly declining due to possible criticism for their negative potential impact on public health concerns and increasing demand for organic food [8]. Hence, several herbal plant products that contain anti-microbial, anti-stress and anti-oxidative properties that can justify their application as phyto-additives in livestock are now attracting more research interest. Garlic (*Allium sativum*), ginger (*Zingiber officinale*) or lemon grass (*Cymbopogon citratus*) is such herbal plant with essential oil that can potentially modulate rumen microbial function for enhancing nutritional quality of high fibrous feed intake [7]. They can also optimizing digestibility in bio-hydrogenation which inhibit methanogenesis and reduce ammonia production in the rumen [9]. Hence, the study was coined to examine the impact of herb oils on nutrient utilisation, lipid profile and methane emissions in goats fed mixed maize/rice straw-hay as alternative basal diets.

II. MATERIALS AND METHODS

A. Study Area:

The study was carried out at the Sheep and Goat Unit of the livestock Teaching and Research Farm of Ambrose Alli University, Ekpoma, Nigeria.

B. Experimental Diets

Green maize and rice straws were obtained as waste from their respective farms within Ekpoma. They were packed separately and transported to livestock farm before being chopped and air-dried under shade to about 80 – 85% of the dry matter to retain their green colour. Thereafter, they were stored in bags and kept on a dry clean cool place to preserve most of their nutrients for several days and the product was subsequently regarded as hay. However, 70% of maize straw-hay was mixed together with 30% rice straw-hay to form basal diets of mixed maize/rice straw-hay before being divided into four parts. Oil (2mg/g) from garlic, ginger or lemon grass was sourced from the university laboratory and 2mg/g was sprayed differently on each part of the mixed straw-hay as an additive daily with exception of control group. The concentrate ingredients that comprised the following 40.00% wheat offal, 23.00% brewery dry grain, 20.00% soybean cake, 12% rice bran, 3.00% bone meal, 1.50% vita-min premix and 0.50% salt were purchased in nearby feed mill to formulate the supplementary diet. However, basal diets and concentrate supplement were used in a ratio of 60:40 respectively, in the experimental diets. Hence, basal diet of mixed maize/rice straw-hay with or without 2mg/g/day of oil additive were used with concentrate supplement to prepare each of the treatment diet. The four prepare designated experimental diets were; MRH_1 (60% maize/rice straw-hay without oil plus 40% concentrate diet which served as the control group), GAH_2 (60% maize/rice straw-hay sprinkled with 2mg/g garlic oil daily plus 40% concentrate diet), GIH_3 (60% maize/rice straw-hay sprinkled with 2mg/g ginger oil daily plus 40% concentrate diet) and LEH_4 (60% maize/rice straw-hay sprinkled with 2mg/g lemon grass oil daily plus 40% concentrate diet).

C. In-vitro Degradation and Methane Production

Rumen fluid used for the *in-vitro* digestion was derived from four goats that were previously fed with diet consisting forage and concentrate in a ratio of 80:20 twice daily. The fluid was collected by oesophageal sampling in the morning before feeding and filtered through two layers of sterile gauze strips to remove plant debris and isolate the rumen fluid. A total of 200mg dried milled standard substrate samples of the diets was measured into 100ml graduated gas tight plastic syringes in six replicates. Each of the syringes was filled with 30ml inoculums that comprised a mixture of medium solution and rumen fluid in a ratio of 2:1 v/v. The artificial saliva contained macro and micro mineral, reseazurin and bicarbonate solution that buffer pH of the rumen fluid as outline by [10]. The tips of the syringes were fitted with a rubber cork tuber equipped with a valve sealed to prevent the escape of gas. Syringes were then incubated at 39^0C for 84hr with occasional shaking. The rate of gas production readings were recorded at three hours interval from 0 to 48hr. Incubation procedure was handled under continuous flowed of anaerobic condition. Three blanks were included in the run to correct for gas production not arising from the substrate fermentation.

Methane was determined from the total gas produced at the post incubation period by introducing 4ml of NaOH (10M) following the method described by [11]. The total volume of gas and percentage methane produced was recorded. Substrate degraded (mg/200mg) was estimated by removing the un-degraded residue for each sample from the initial quantity incubated. The residue was recovered by filtering and drying at 105^0C for 12hr. Neutral detergent fibre (NDF) degradation was also determined by subtracting the residue of NDF from that of the substrate incubated. The difference was then related as a percentage of the sample incubated.

D. Experimental animals' procedures

After the *in-vitro* study, twenty four West African dwarf male goats with initial average live body weight of 8.00 ± 0.64kg that were sourced within Ekpoma livestock farm were used for the experiment. The animals were confined in individual pens during a preliminary period of 14 days for adaptation and prophylactic treatments to control diseases. Thereafter, they were randomly assigned to each of the four treatment diets that were replicated three times with two sheep per replicate in a completely randomized design.

The goats were housed in 1 x 1.5m individual semi-open pens that were equipped with feeders and water troughs. Feeds (concentrate supplement first before basal diet) were offered at 5% dry matter basis of their body weight at about 8:30am and 4:30pm daily. The ratio of mixed maize/rice straw-hay to concentrate supplement was used to determine the proportion of diet that was offered daily to each goat. The quantity of feed given was adjusted weekly according to live weight change. Goats also had free access to drinking water and the study duration was 90 days exclusive of 14 days adaptation period.

E. Growth and Rumen Indices

The average daily feed intake was determined by the difference between the amount of feed offered and refusal. The initial body weight of goats were weighed and recorded at the onset of the experiment and subsequently once every week with measuretech® hanging scale prior to morning feeding to estimate change in body weight. Values obtained from daily feed intake and body weight gain were used to calculate feed conversion ratio.

Rumen study was preceded by growth rate measurement of goats. Rumen liquor sample was collected from each goat three hours post feeding on day 75 through a stomach tube and inserted through the oesophagus. The first portion (about 30ml) of the liquor collected was discarded to reduce saliva contamination. The liquor was made free of coarse particles by straining through layers of cheese cloth. The pH of rumen liquor was measured immediately after collection with digital pH meter. About 10 ml fraction of the sample was acidified with a 1m sulphuric acid solution to estimate ammonia nitrogen (NH_3 – N) concentration and total volatile fatty acid (VFA). Another sub-sample of 10ml was treated with 2ml of 25% meta-phosphoric acid (prepared 5N sulphuric acid) kept overnight at 4^0C and centrifuged at 584rpm for 15min to determine individual fraction volatile fatty acids.

F. Lipid Profile and Nutrient Digestibility

After the first 74 days of the feeding trial and one day rumen study, blood samples were collected from goats on the following day at 8.00am before morning feeding through vein puncture. The blood was placed into anticoagulant free tube and later centrifuged at 4000 xg for 20 minutes for the separation of serum and kept at -20 ^{0}C until further analysis. Blood lipid parameters were determined as total cholesterol, high density lipoprotein, low density lipoprotein and triglycerides.

Thereafter, goats were transferred to the metabolic cages for separate collection of faeces and urine. They were allowed for 7days adaptation period, before a 7 day of digestibility and nitrogen retention assessment. Feed offered, refused, voided faeces and urine were collected and recorded daily. After measurement, faecal samples for each goat was bulked, mixed properly and about 10% sub-samples were pooled and kept in plastic bags in refrigerator. Urine sub-samples (5%) were collected in plastic bottles with 4 drops of diluted sulphur acid (10% H_2SO_4) to prevent loss of nitrogen due to volatilization and freeze (-20%). Thus, the apparent digestibility of nutrient was calculated using the formula:

$$\text{Nutrient digestibility: } \frac{\text{nutrient intake} - \text{nutrient in faeces}}{\text{Nutrient intake}} \times \frac{100}{1}$$

Nitrogen balance was determined as the differences between nitrogen intake and nitrogen excreted from faeces and urine. The nitrogen retention percentage was computed from the nitrogen balance expressed as a percentage of nitrogen intakes. This follows a post treatment period where goats were returned to their pens before termination.

G. Chemical Analysis

Feeds, experimental diets, and faecal samples were dried for 48 hours at 60^0C in a forced – air oven to determine the dry matter (DM) content. They were milled to pass through a 1mm screen in a Willey mill for proximate analysis following the procedures of [12], while neutral and acid detergent fibre were determined by [13]. Total nitrogen urine was measured by the Kjeledahl procedures as outline by [12]. Lipids profile was determined by using commercial coloremitrickits supplied by Biodiagnostic Company for laboratory services as reported by [14]. Rumen NH_3 – N concentration was determined by the method previously reported by [15], while total VFA and its fractions were measured according to the modified procedures reported by [16].

H. Statistical Analysis

Data generated from the study were subjected to analysis of variance using the general linear model (GLM) in ANOVA programme of the MINITAB [17] to determine the effects of oils on dietary treatments of the various parameters studied. Where significant difference occurs, means were separated by Duncan's multiple range test within the statistical package [18]. The mathematical model used for the analysis was as follows:

Yijk = G + Ai + eijk

Where;

Yijk = independent variable (growth, digestibility........)

G = overall mean of the observed variable

Ai = effect due to i^{th} treatment diets

Eijk = effect of random residual error

III. RESULTS

In the feeds examined (Table 1), maize straw-hay recorded the highest content of crude fibre and its fractions but lowest in ash. Rice straw-hay was relatively lower in crude protein, ether extract and nitrogen free extracts values as compared with concentrate supplement and maize straw-hay. However, there was no much discrepancy in values obtained in dry matter among the feeds. Overall, treatment diets showed remarkable differences in values registered in dry matter, crude fibre, ether extract and nitrogen free extract. Diets with oil ($GAH_{2,}$ GIH_3 and LEH_4) showed similar lower values for dry matter, crude fibre and nitrogen free extract than diet $MRH_{1..}$ Test diets had relatively higher variable values in ether extract according to the type of plant oil used than the control diet. Generally, diets recorded similar higher values for crude protein and ash with no remarkable difference among treatments.

Table 1: Proximate composition (%DM) of feeds and experimental diets

	Feeds				Experimental diets		
	MS	RS	CS	MRH$_1$	GAH$_2$	GIH$_3$	LEH$_4$
Dry matter	93.02	95.47	94.53	92.14	88.32	90.45	89.76
Crude protein	4.98	3.89	24.10	12.44	12.51	12.49	12.47
Ether extract	0.91	0.73	4.12	2.17	3.14	3.23	3.16
Crude fibre	40.62	38.68	17.85	31.15	30.99	31.04	31.07
Ash	5.85	12.92	6.22	7.34	7.41	7.43	7.36
Nitrogen free extract	39.66	38.25	43.24	44.61	35.41	37.25	36.70
NDf	75.03	71.95	38.07	68.76	63.68	65.04	67.05
Acid detergent fibre	48.51	39.72	20.35	36.51	30.91	33.73	35.84

MS = *Maize straw-hay*, RS = *Rice straw-hay*, CS = *Concentrate supplement*, NDF = Neutral detergent fibre

There were disparities in the distribution of fatty acid percentage components in garlic, ginger and lemon grass (Table 2). Lauric, myristic, oleic and linoleic acids were found to be higher in values for lemon grass than garlic and ginger. On the other hand, ginger and lemon grass showed fairly lower values for palmitic and stearic acids as compared with garlic.

Table 2: Fatty acid profile (%) of garlic, ginger and lemon grass

Parameters	Garlic	Ginger	Lemon grass
Saturated fatty acid			
Lauric acid [CH_3 $(CH_3)_{10}$ COOH]	1.08	1.00	1.77
Myristic acid [CH_3 $(CH_3)_{12}$ COOH]	0.51	0.40	4.21
Palmitic acid [CH_3 $(CH_3)_{14}$ COOH]	1.30	1.20	0.23
Stearic acid [CH_3 $(CH_3)_{16}$ COOH]	1.50	1.40	0.001
Unsaturated fatty acid			
Oleic acid CH_3 $(CH_2)_5$ CH = $CH(CH_3)_7$ COOH	0.3	0.4	2.72
Linoleic acid $CH_3(CH_2)_4CH=CHCH_3CH=CH(CH_2)=$ COOH	1.4	1.3	2.13

Differences existed significantly ($p<0.05$) among values recorded in response to degradability of treatment diets (Table 3). Gas production and substrate degraded had the lowest values in test diets (GAH$_2$ and GIH$_{3)}$.but highest in control group (MRH$_{1)}$.. Methane production and neutral detergent fibre degradation were similar and low in values registered for GIH$_3$ and LEH$_4$ but higher in MRH$_1$ as compared with GAH$_2$ in the treatment diets.

Table 3: Gas production, methane emissions, substrate degraded and neutral detergent fibre (NDF) degradation of diets containing different plant oil additives

	Treatments Diets				SEM ±
	MRH$_1$	GAH$_2$	GIH$_3$	LEH$_4$	
Gas production (ml)	28.47^a	19.79^c	20.85^c	25.98^b	0.42
Methane production (%)	32.38^a	14.55^c	17.73^{bc}	20.02^b	0.35
Substrate degraded (%)	68.98^a	50..41^c	55.39^c	62.47^b	0.86
NDF degradation (%)	58.34^a	39.10^c	47.02^b	50.52^b,	0.59

^{a,b,c} Means in the same row with varying superscript differ significantly ($P < 0.05$)

Generally, there were dietary effects on voluntary intake of feeds, goats on diets treated with oils significantly ($p< 0.05$) consumed more than those on control diet (Table 4). Live weight gains were also influenced by the type of diets, but initial weight of goats did not differ ($p>0.05$) among diets. However, goats on diet without additives had the least final weight and daily weight gains as compared with diets sprayed with garlic, ginger or lemon grass oil. The best feed conversion ratio values were avidly recorded by goats on diets GAH$_2$ and GIH$_3$, followed by LEH$_4$ before those offered MRH$_{1.}$

Table 4: Effect plant oils on growth performance of goats fed mixed maize/rice straw-hay as alternative basal diets.

Parameters	Experimental Diets				SEM ±
	MRH$_1$	GAH$_2$	GIH$_3$	LEH$_4$	
Feed intake(g/day)	298.19^c	302.45^b	321.73^a	318.49^a	1.42
Initial body weight (kg)	8.73	8.58	8.60	8.65	0.03
Final body weight (kg)	11.42^b	12.37^a	12.09^a	11.79^{ab}	0.57
Total weight gain (kg)	2.69^b	3.79^a	3.49^a	3.14^a	0.14
Daily weight gain (g/day)	36.35^c	51.22^a	47.16^b	42.43^b	0.87
Feed conversion ratio	8.20^a	5.91^c	6.82^{bc}	7.51^b	0.09

^{a,b,c} Means in the same row with varying superscript differ significantly ($P < 0.05$).

In the current study, diets were not significantly ($p>0.05$) affected by additives when considering the major differences found in the rumen pH and proportion of butyrate. Changes in ammonia nitrogen (NH_3-N) and total volatile fatty acids (VFA) concentration in rumen fluid were significantly ($p<0.05$) influenced by additive sources with goats on control group relatively higher than the test diets. The proportion of acetate followed the same pattern of variation as in total VFA. It is interesting to know that the fraction of propionate in rumen fluid of goats were significantly ($p<0.05$) higher in test diets than the value recorded in control group.

Total cholesterol values were significantly ($p<0.05$) low in test diets with minimum level recorded in LEH$_4$. However, the control diet had the highest concentrate levels of low density lipoprotein and triglycerides than the test diets. Feeding ration that contained oil additives led to significant ($p<0.05$) increased in high density lipoprotein than ration without oil.

Table 5: Rumen fermentation and lipid profile of goats as influenced by plant oils

Parameters	Experimental Diets				
	MRH1	GAH_2	GIH_3	LEH_4	SEM ±
Rumen pH	6.24	6.79	6.77	6.71	0.04
NH_3-N (mg/dl)	9.89^{a}	4.49^{c}	4.95^{bc}	5.02^{b}	0.10
Total VFAs (mM)	79.75^{a}	61.89^{c}	63.57^{c}	65.01^{b}	0.93
Acetate (mol/100ml)	61.03^{a}	47..00^{c}	46.98^{c}	49.12^{b}	0.56
Propionate (mol/100ml)	18.99^{c}	29.42^{a}	27.82^{b}	25.96^{b}	0.27
Butyrate (mol/100ml)	2.97	2.00^{b}	2.02	2.05	0.04
Lipid profile					
Total cholesterol (mg/dl)	78.96^{a}	68..52^{c}	70.84^{b}	66.79^{c}	0.48
HDL cholesterol (mg/dl)	35.02^{c}	44.92^{ab}	42,70^{b}	47.33^{a}	0.16
LDL cholesterol (mg/dl)	43.94^{a}	23.60^{c}	28.72^{b}	21.46^{c}	0.29
Triglycerides (mg/dl)	62.19^{a}	51.06^{c}	56.29^{b}	53.49^{c}	0.75

^{a,b,c} Means in the same row with varying superscript differ significantly ($P < 0.05$)

NH_3-N =Ammonia nitrogen, VFAs = Volatile fatty acids, HDL= High density lipoprotein, LDL = Low density lipoprotein.

There were remarkable difference in apparent nutrient digestibility with exception of ash that was not significantly ($p>0.05$) affected by diets (Table, 6). Digestibility of dry matter, crude protein and crude fibre were significantly ($p<0.05$) higher for diets with oil treatment but relatively lower for control diet. Diets GAH_2 and LEH_4 registered increase digestibility coefficient of ether extract as compared with MRH_1 and GIH_3, which were considerably lower in values. However, nitrogen free extract and crude fibre fractions digestibility followed this same trend as crude fibre digestibility.

Nitrogen (N) intake and retention showed significant ($p<0.05$) higher values in test diets than diet without oil additive. Differences were not strictly comparable but more pronounced for goats on control diet than the test diets

Table 6: Nutrient digestibility (%) and nitrogen balance of goats fed mixed maize/rice straw-hay as alternative basal diets.

Parameters	Experimental Diets				
	MRH1	GAH_2	GIH_3	LEH_4	SEM ±
Dry matter	65.81^{c}	73.02^{a}	71.54^{b}	70.96^{b}	0.76
Crude protein	60.14^{c}	71.09^{a}	69.87^{b}	68.75^{b}	0.83
Crude fibre	58.33^{c}	70.76^{a}	70.02^{a}	69.64^{b}	0.92
Ether extract	52.42^{b}	60.25^{a}	55.91^{b}	60.01^{a}	0.86
Ash	70.31	70.68	70.59	70.85	0.03
Nitrogen free extract	62.94^{c}	72.93^{a}	71.01^{a}	69.92^{b}	0.69
Neutral detergent fibre	53.07^{c}	68.85^{a}	67.95^{a}	64.69^{b}	0.58
Acid detergent fibre	15.57^{c}	21.92^{a}	20.87^{a}	19.44^{b}	0.74
Nitrogen balance					
Nitrogen (N) intake (g/day)	8.97^{b}	9.11^{a}	9.08^{a}	9.05^{a}	0.13
Faecal N-output (g/day)	3.00^{a}	2.14^{b}	2.19^{b}	2.22^{b}	0.05
Urinary N-output (g/day)	1.99^{a}	1.02^{b}	1.42^{b}	1.69^{b}	0.08
N-retention (g/day)	3.98^{b}	5.95^{a}	5.47^{a}	5.14^{a}	0.06
N-retention % intake	44.37^{c}	65.31^{a}	60.24^{ab}	56.80^{b}	0.54

^{a,b,c} Means in the same row with varying superscript differ significantly ($P < 0.05$)

IV. DISCUSSION

A. Feed Composition and In-vitro Methane Emissions

Maize and rice straws consist predominantly of cell wall that comprised cellulose, hemi-cellulose and lignin. Their contents in this study were poor in crude protein and ether extract but relatively high in ash, crude fiber and its fractions especially neutral detergent fibre. Thus, feeding only these straws to ruminants do not provide enough nutrients to maintain high production due to their low degradability caused by lignifications and silicification. Sarnklong [19] observed that many by-products from the human food industry have high biomass, low crude protein content of approximately 3 to 4% with high content of crude fibre of approximately 35 to 48%. Thus, supplementation of a concentrate diet with more accessible energy and protein sources to crop-residues will improve goat performance. Addition of concentrate supplement to the basal diet of mixed maize/rice straw-hay caused variation in nutrients of treatment diets with increased in crude protein content above the reported 8%CP minimum value required for ruminant performance [20]. However, nutrient composition of crude fibre in maize and rice straws obtained was slightly different from the reported values (41.79 and 39.86 %) of [21] and [19] respectively. Crop varieties, growing seasons and morphological characteristics of the straws could probably responsible for the differences observed.

Herb plant oils possesses phytogenic compounds that have the ability to modify and optimize rumen functions for better digestion and maximize utilization efficiency to increase intake of fibrous feeds (Al-Azazi et al 2018). They also have health benefits and improve energy efficiency by inhibitory methane emissions in the rumen when used as additives. Sarnklong [19] emphasized that it is necessary to supply the rumen micro-organisms with nutritive elements and additives needed for self-multiplication with degradation of cell walls of straw to suitable condition for maintenance of good cellulolysis. However, fatty acid profile of garlic, ginger and lemon grass obtained were not up to 6% that could cause negative effect on rumen fermentation as reported by [23].

The inhibitory effects of essential oil on *in-vitro* methane production and fibre degradation of mixed maize/rice straw-hay could be attributed to the anti-microbial and bactericidal efficacy properties found in herbal plant. Perhaps, this methane suppression could not adversely affected fibre degradation and gas production in the study, explaining the beneficial effects of herbal oil to ensure adequate microbial breakdown of lignin materials in the rumen. This implies that, the bioactive components of the essential oil in mixed straw-hay based-diets could give better correlation between methane reduction and activeness of fibre degrading microbes. Earlier reported work had similar findings on methane reduction with concomitant decrease in feed degradation without substantial effect on rumen fibre degradation when phytogenic feed additives were added to high fibrous feeds [24]. The previous study of [21] also noted how methane reduction did not fully decrease fibre degradation when 5mg/g cinnamon powder was used as additive in maize stover-based diets in an *in-vitro* medium.

B. Intake and growth performance

The mechanism regulating voluntary intake of low quality feeds is still not fully understood. The generally accepted theory of feed intake regulation for poor quality roughages is the capacity of the rumen to process the feed as the major determining factor for voluntary intake of feeds. Rumen processing capacity is characterized by rumen fill, rate of degradation of potentially degradable matter with rate of passage out of the rumen [19]. Goats on control diet that had low feed intake was because of poor degradability that resulted from slow rates of disappearances in the rumen with low rates of passage through the rumen which led to poorly fermented feeds. Furthermore, goats on diet with garlic oil tend to consume little less regular than other oil treated diets because of the strong smell and unpleasant flavour which gave a repulsive odour and pungent taste in the diet [25].

The difference in feed intake was however reflected positively in improved weight gain and better feed conversion of goats on test diets. The presences of phytogenic components of alkaloids and polyphenols which enhanced palatability of the ration could be the reason for the various changes seen in the intake. This direct action was an indication of colonization by rumen microorganism [26] that brings about better functioning of the rumen to enhance feed intake and efficiency that allow adequate nutrient balance at the site of metabolism. This could probably provide sufficient energy to maximize the efficiency utilization of available protein that further confirm the superiority of the diets for better weight gain. These findings are in agreement with the report of [27] who found that addition of plant oil up to 2.2mgl reduced methane emissions and increase performance but higher inclusion level to the extent of 300mgl^{-1} reduced not only methane but feed utilization. The values of daily weight gain and FCR obtained in this study were in line with the reported values of [28] for goats on diets treated with garlic oil.

C. Rumen fermentation and blood profile

There is evidence that indicates the activeness of oil bioactivity mechanisms against rumen function in selecting the number of enzymes entering microbial cell membrane which modified their conformation and stability in rumen activity [29]. Thus, the neutralization of rumen ecosystem by the herbal oil could possibly show a better environment that kept the pH of the rumen within normal range of values (6.5 – 7.0) as reported by [30] for optimal microbial fermentation. The decreased observed in the rumen ammonia nitrogen (NH_3-N) concentration for goats on test diets showed the inhibiting factor of polyphenols that was sensitive to the ammonia production process. A more likely explanation was the effect of tannin in the herbal oil that reacted with the diets to increase the escape of protein from the rumen for more efficient enzymic digestion in the intestine [9]. This further shows the reduction in number and diversity of hyperammonia producing bacteria to minimize ammonia production rates from conserved amino acid. However, reduction in NH_3 – N) that concomitant with higher propionate production in goats on test diets were probably compensated by increase in energy production for goats. As pointed out by several writers [29], [31] propionate is the major precursor of carbohydrate in volatile fatty acids, this implies that the oil enhanced the diets to supply higher hepatic gluconeogenic substrate that was required for synthesis of glucose.

Cholesterol is an essential component of animal cell membrane that serves as a precursor for biosynthesis of steroid hormones, bile acid and vitamin D. High level of serum cholesterol in the blood chemistry has been noted to have positive correlation with cardiovascular diseases [23]. In the current study, influence of plant oil reduced serum total cholesterol and low density lipoprotein (LDL) in the test diets due to stimulation effect of unsaturated fatty acids on the cholesterol excretion into intestine and the oxidation of cholesterol to bile acid. This fact is in agreement with the report of [32] who investigated that herb plants lower the levels of monosaturated fatty acids and the atherogenic pathological effects on the synthesis of cholesterol by hepatocytes or fractional re-absorption from the small intestine. Furthermore, the results of triglyceride revealed that a negative relationship existed between cholesterol and triglycerides which further attest the crucial effects of phytogenic compounds on decreasing serum triglycerides, since it could act as cholesterol fibrate.

High density lipoprotein (HDL) is the main transport form of cholesterol from peripheral tissue to the liver which later excreted through the bile. The level of HDL in the serum is inversely related to the incidence of myocardinal infraction. Hence, diets with oil seem to be beneficial as it increased the level of HDL in cholesterol. El-Hawy [14] reported that increase in concentration of HDL particles are strongly associated with decreasing accumulation of atherosclerosis which eventually results in sudden plaque ruptures, cardiovascular disease and other vascular diseases.

D. Digestibility and nitrogen retention

It was apparent that addition of plant oil to basal diet of mixed maize/rice straw-hay improved the digestibility of nutrients in present study. Differences in selective of antimicrobial action against certain rumen-organism could probably reflect in the efficient digestibility encountered by the goats. There was a considerable decrease observed in nutrient digestibility for goats on control diet, this indicates poor activity of digestive enzymes, which adversely reduced cell wall carbohydrate and caused low feed degradability. Various authors [7], [19] have suggested that negative response of high fibre feeds digestibility is due to inability of rumen microbes to act effectively on feed degradability. Interestingly, addition of herb oils, did not affect digestibility of ash but ether extract was only increased in diets treated with garlic or lemon grass oil. The reason for this inconsistency is presumably depending on fatty acid profile. Study reported in literature had shown [14] that herb plants improve utilization of unsaturated fatty acids to increase palatability and metabolizing energy efficiency better than saturated fats.

The inhibition of most rumen microbial degradation of protein content by oil additive had resulted in reducing faecal and urinary N-output in the test diets. Nitrogen retention which is related to biological value of crude protein which is readily digestible and available for absorption by animals was highest in test diets. This explains the presence of optimum content of crude protein in the diets that was utilized and retained by the goats.

V. CONCLUSION

The use of chemical treatments on maize and rice straws have gone a long way in improving the voluntary intake and degradability than straw without treatment, but their practical use is still restricted in areas of cost, potential negative consequences on environments and human safety. However, the study discovered that the use of herb plant oil as natural additive to basal diets of mixed maize/rice straw-hay was one potential alternative to provide a more practical and environmental friendly approach for enhancing their nutritive value.

Thus, the application of 2mg/g/day oil of garlic, ginger or lemon grass to the feeding of 60% mixed maize/rice straw-hay basal diet with 40% concentrate supplement enhanced intake, performance and suppressed methane emissions. This improvement in nutrient utilization, lipid profile with reduction in methane production was more pronounced in diets treated with oil from garlic or ginger than lemon grass.

ACKNOWLEDGEMENT

This research was supported by Faculty of Agriculture Teaching and Research Farm of Ambrose Alli University, Ekpoma, Nigeria.

REFERENCES

[1] FAO (Food and Agricultural Organisation, 2002). FAOSTAT data(http;//faostat.fao.org/faostat/collection?subset=agriculture, accessed on 25-April-2010). Feed Science and Technology, 114: 31-41.

[2] Kosgey I.S, R L Baker, H M J Udo and J A M Var Arendonk (2006). Successes and failures of small ruminant breeding programs in the tropics: a review. Small Rumin. Res., 61:13-28.

[3] Ibrahim, T.A, Abdu, S.B, Hassan,M.R,. Yashim, S.M. and Adamu, H.Y. (2016). Growth performance of red sokoto bucks fed inclusion levels of raw and soaked roselle (*Hibiscus sabdariffa* L) seeds in rice bran based diets. Nigerian Journal of Animal Science, 18(2) :434-443.

[4] Al-Masri, M. R. (2020). *In-vitro* nutritional and fermentation characteristics of *Medicago arborea* at different growth stages and their relationship to gas production. Livestock Research for Rural Development, 32(9)

[5] Yanti,Y and Yayota, M (2017). Agricultural by-products as feed for ruminants in tropical area: nutritive value and mitigating methane emission. Reviews in Agricultural Sciences, 65-76. https://www.jstage.jst.go.jp/article/ras/5/0/5_65/_pdf

[6] Kim, E.T. Kim, C. H, Min, K. S. and Lee, S. S. (2012). Effects of plant extracts on microbial population, methane emission and ruminal fermentation characteristics in *in-vitro*. Asian-Australasian Journal of Animal Sciences 25 (6): 806-811. http;//dx.dio.org/10.5713/ajas.2011.11447.

[7] Candyrine S C L, Jahromi M. F, Ebrahimi M, Chen W L, Rezaei S, Goh Y M, Abdullah N and Liang J B (2019). Oil supplementation improved growth and diet digestibility in goats and sheep fed fattening diet. Asian –Australasian Journal of Animal Sciences, 32, No 4: 533 – 540

[8] Belewa M A, Okukpe K M, Oladipo F O, Kareem I, Kolawole F I, Muhammed-Lawal A, Ahmed O and Badmos A H A (2011). Lemon grass (Cymbopogon citratus): A plant for future medicinal edible oil. Medicinal plants-International Journal of Phytomedicines and Industries, 3(2): 169 – 171.

[9] Kirisci A and Kamalak A (2019). Supplementing sainfoin (*Onobrychis viciifolia*) hay with garlic oil; effects on rumen *in-vitro* gas production, digestibility and ammonia production. Livestock Research for Rural Development, 31(4):1 – 5. http://www.lrrd.org/lrrd31/4/akama.31055.html.

[10] Menke K H and Steingass H (1988). Estimation of the energetic feed value obtained from chemical analysis and *in-vitro* gas production using rumen fluid. Animal Research and Development, 28: 47-55

[11] Fievez V, Babayemi, O. J and Demeyer D (2005). Estimation of direct and indirect gas production in syringes: a tool to estimate short chain fatty acid production requiring minimal laboratory facilities. Animal Feed Science and Technology (123-124): 197-210

[12] AOAC (1990). Official Methods of Analysis. Association of official analytical chemist, 15th Edition (Khelrick, editor) Arlington pp 1230.

[13] Van Soest, P. J. Robertson, J B. and Lewis, B. A. (1991). Methods of dietary fibre, neutral detergent fibre and non-starch polysaccharides in relation to animal nutrition. Journal of Dairy Science 74: 3583-3597. http;//dx.doi.org/10.3168/jds.S0022-0302(91)78551-2.

[14] El-Hawy, A.S, Abdalla, E.B, Gawish, H.A, Abdou, A and Madany, M.E. (2018). Effects of alternative dietary protein of *Nigella sativa* on some haematological, biochemical and immunological responses of pregnant Barki ewes. Australian Journal of Basic and Applied Sciences, 12 (7) : 148 – 154.

[15] Corredu F, Nudda A, Battacome G., Boe R, Francesconi A H D and Pulna G (2015). Effects of grape seed supplementation, alone or association with linseed in ruminal metabolism in Sards dairy sheep. Animal Feed Science Technology, 199, 61 – 72.

[16] Mor P, Bals B, Kumar S, Tyagi N, Reen, J. K, Tyagi, B., Choudhury P K and Pyagi, A K (2019). Influence of replacing concentrate mixture with AFEX pellets on rumen fermentation, blood profile and acetamide content in the rumen of crossbred (Alpine x Beetle) female goats. Small Ruminant Research, 170: 109 – 115..

[17] MINITAB (2000). Minitab Statistical software, Release 10.2 Minitab Inc. State College PA, USA

[18] Steel R G D and Torrie J H (1990). Principle and procedure of statistics. A Biometrical approach 3rd edition. MacGraw Hill Book Company. New York, USA.

[19] Sarnklong, C., Cone, J.W., Pellikaan, W and Hendriks, W.H. (2010). Utilization of rice straw and different treatments to improve its feed value for ruminants; A review. Asian-Australasian Journal of Animal Science, 23 (5) : 680 – 692.

[20] Norton B W (2003). Tree legumes and dietary supplements. In: forage tree legumes in tropical agriculture . Gutteridge, R. C. and Shelton (Ed) CAB International Walling-ford Oxon, Pp 192 – 201

[21] Aderinboye, R. Y. Salami, T.A. Adelusi, O.O., Adebayo, K.O. Akinbode R. M. and Onwuka, C.F.I. (2020). Effect of cinnamon powder on methane emission and degradation of maize stover-based substrate in an in-vitro medium. Livestock Research for Rural Development, 36(6), *Arctile # 90*http://www.lrrd.org/lrrd36/1*aderi32090.html*.

[22] Al-Azazi A S H., Baraka T A and Khalaf A M (2018). Effect of ginger powder (*Zingiber officinale*) on selected rumen and blood serum constituents in sheep. Indian Journal of Applied Research, 8(4): 450 – 457.

[23] Almeida O C, Pires A V, Susin I, Gentile R S. Mendes C O, Queiroz M A A., Ferreira E M and Eastridge M I (2013). Milk fatty acid profile and arterial blood milk fat precursors concentration of dairy goats fed increasing doses of soybean oil. Small Ruminant Research, 114; 152 – 160.

[24] Patra A.K.and Saxena J (2010). A new perspective on the use of plant secondary metabolites to inhibit methanogenesis in the rumen. Phytochemistry, 71: 1198 – 1222

[25] Tapsell L C and Hemphill I (2006). Health benefits of herbs and spices: The past, the present, the future. Medical Journal of Australia., *185*, (4 suppl); 54 – 524.

[26] Van Soest, P. J. (2006). Review rice straw, role of silica and treatments to improve quality. Animal Feed Science and Technology, 130:137-171.

[27] Castillejos S, Catsamigtia and Ferret A (2006). Effect of essential oil active compounds on rumen microbial fermentation and nutrient flow in *in-vitro* systems. Journal of Dairy Science, 89: 2649 – 2658.

[28] Okoruwa M I and Edoror O.M (2019). Effects of garlic oil supplementation on intake, digestibility, performance and rumen functions of goats fed silage based-diets. European Journal of Nutrition and Food Safety, 10(2); 104 – 115.

[29] Zulfa I H. Bachruddin Z and Kumiawati A (2019). Effects of lemon grass leaves as essential oil sources on rumen microbial ecology and nutrient digestibility in an *in-vitro* system. Pakistan Journal of Nutrition, 18: 254 – 259.

[30] Calsamiglia S, Busquet M. Cardozo P W, Castillejos L and Ferret L (2007). Essential oils as modifiers of rumen microbial fermentation. Journal of Dairy Science, 90: 2580 – 2595.

[31] Patra A K (2011). Effects of essential oils on rumen fermentation, microbial ecology and ruminant production. Asian Journal of Animal and Veterinary Advances, 6; 416 – 428.

[32] Padhye, S, Banerjee, S, Ahmad, A, Mohammad, R, Sarkar, FH (2008). From here to eternity - the secret of Pharaohs: Therapeutic potential of black cumin seeds and beyond. Cancer Therapeutics 6, 495-510.