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Comparative effect of garlic (*Allium sativum*) and ginger (*Zingiber officinale*) and their combination on growth, rumen ecology and apparent nutrient digestibility in sheep

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Abstract

Manipulation of rumen environment using herbal mixtures with antioxidant and antibacterial potentials will improve rumen health and animal productivity. This study undertook to assess the effect of supplementing garlic and ginger powder and their combination on rumen ecology and nutrient utilization of sheep. Sixteen mixed breed rams were allotted to four experimental diets in a completely randomized design. The experiment lasted for 91 days. The four diets were Control (No garlic or ginger powder), gap (garlic powder 2.5 g/kg diet), gip (ginger powder 2.5 g/kg diet) GGP (garlic powder 1.25 g/kg diet + ginger powder 1.25 g/kg diet). Data on rumen ph, metabolites, microbial count, and isolation, nutrient digestibility was statistically analyzed using one-way analysis of variance as provided in the GLM of SPSS (version 23). Results revealed an increase ($p<0.05$) indaily weight change, rumen total volatile fatty acids (tvfas), acetate, propionate and butyrate, bacteria count, gram-negative bacteria, fungi species such as Rhizopus sp., apparent digestibilities of dry matter (DM), ash, NDF and ADF with supplementation of garlic and/or ginger and their combination. The combination of garlic and ginger gave a comparative better ($p<0.05$) result in some of the parameters than either garlic or ginger singly. It was concluded that a combination of 1.25 g/kg diet of garlic and ginger each would achieve an overall better performance of the rumen that feeding 2.5 g/kg diet of garlic or ginger singly.

Keywords: Garlic, Ginger, Sheep, Rumen, nutrient digestibility

Un Effet comparatif de l'ail (Allium sativum) et du gingembre (Zingiber officinale) et de leur combinaison sur la croissance, l'écologie du rumen et la digestibilité apparente des nutriments chez les moutons

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Résumé

La manipulation de l'environnement du rumen à l'aide de mélanges d'herbes aux potentiels antioxydants et antibactériens améliorera la santé du rumen et la productivité animale. Cette étude a entrepris d'évaluer l'effet de la supplémentation en poudre d'ail et de gingembre et leur combinaison sur l'écologie du rumen et l'utilisation des nutriments des moutons. Seize béliers de races mixtes ont été attribués à quatre régimes expérimentaux dans une conception complètement aléatoire. L'expérience a duré 91 jours. Les quatre régimes étaient Contrôle (sans ail ni gingembre en poudre), le 'gap' (ail en poudre 2,5 g / kg régime), le 'gip' (gingembre en poudre 2,5 g / kg régime) le 'GGP' (ail en poudre 1,25 g / kg régime + gingembre en poudre 1,25 g / kg régime). Les données sur le pH du rumen, les métabolites, la

numération microbienne et l'isolement, la digestibilité des nutriments ont été analysées statistiquement en utilisant une analyse unidirectionnelle de la variance telle que fournie dans le GLM de SPSS (version 23). Les résultats ont révélé une augmentation (p <0,05) du changement de poids quotidien, des acides gras volatils totaux du rumen (tvfas), de l'acétate, du propionate et du butyrate, du nombre de bactéries, des bactéries gram-négatives, des espèces de champignons comme Rhizopussp., Des digestibilités apparentes de la matière sèche, cendres, le 'NDF' et le 'ADF' avec supplémentation en ail et / ou gingembre et leur combinaison. La combinaison d'ail et de gingembre a donné un meilleur résultat comparatif (p <0,05) pour certains des paramètres que l'ail ou le gingembre seuls. Il a été conclu qu'une combinaison de 1,25 g / kg de régime d'ail et de gingembre chacun permettrait d'obtenir une meilleure performance globale du rumen qu'une alimentation de 2,5 g / kg d'ail ou de gingembre séparément.

Mots clés : ail, gingembre, mouton, rumen, digestibilité des nutriments

Introduction

Improving the efficiency of rumen fermentation has remained a veritable tool in improving performance in livestock production. Such improvement in rumen fermentation will not just affect the productivity of the animal; it will also have an intense effect on the output of waste products from an animal system such as methane, which pollutes the environment. Efforts are going on to find safer rumen-modulating herbal feed additives (hfas), which have a specific and desirable impact on the productivity of ruminants without polluting the environment. The presence of a good number ofplant secondary metabolites/phytochemicals in hfas has given rise to a success story in protecting predators, pathogens, and environmental stress in animals (Iason, 2005). Garlic (Allium sativum) comprisessignificant alkaloids such as allin, ajoene, allicin, and diallyl sulfide Sallylcysteine exhibiting antibacterial, anti-inflammatory, antiseptic, antiparasitic and immunomodulatory properties (Khan *et al.,*2012). Ginger (Zingiber officinale) comprises active ingredients such are gingerdoine, gengerdiol, and gingerol (Ziaur-Rehman *et al.,*2018). These plant herbs (garlic and ginger) have been shown to manipulate rumen fermentation and modulate the microflora in ruminants for improved performance (Zhang *et al.,* 2011; Tag El-Din *et al.,* 2012; Wanapat *et al.,* 2013, Muhammad *et al.,* 2016; Ikyume *et al.,* 2017; Ikyume *et al.,* 2018; Sahli*et al.,* 2018). Rumen ph was affected by garlic powder supplementation in goats with an inhibition effect on gram-positive bacteria while total volatile fatty acid (TVFA), acetate (A), butyrate (B) propionate (P) and A:P ratio were not affected by garlic powder supplementation (Ikyume *et al.,* 2017). While total volatile fatty acid (VFA) concentration decreased, the fatty acid compositions, acetate-to-propionate ratio, ph, and ammonia-N concentration were unchanged by the addition of ginger powder in sheep (Zhang *et al.,* 2011). Besides, while Crude protein digestibility significantly decreased with increased garlic powder supplementation, dry matter, crude fiber, ether extract, ash, neutral detergent fiber, and acid detergent fiber were not affected by garlic powder supplementation(Ikyume *et al.,* 2017). The combination of these two herbs could complement each other, therefore, improving the performance of the animal. Also, there is a paucity of information on the combined effect of these herbs on the

growth performance, rumen fermentation pattern, microbial flora, and nutrient utilization. Hence, this research sought to assess the comparative effect of garlic and ginger powder and their combination on growth performance, rumen ecology, and nutrient utilization of sheep.

Materials and methods

Experimental site

The experiment was carried out at the Animal Science Teaching and Research Farm of the Federal University of Agriculture, Makurdi. The site lies between latitude 7° 44' 1.50" N and longitude 8° 31' 17.00" E

Collection and preparation of plant bulbs material

The garlic and ginger bulbs were purchased from the local market in fresh condition. The bulbs were oven-dried at a temperature of 70 °C for three days. After drying, the plant materials were ground with the help of an electric grinding machine.

Experimental animals, management and diet

Sixteen cross breed rams (Yankasa and West African Dwarf breeds) used in this study were divided into four groups and assigned to four treatment groups with each animal serving as a replicate. The rams were purchased from Lafia town, Nasarawa State, Nigeria. They were quarantined for four weeks. During the quarantine period, oxytetracycline LA (1 ml/10 kg) was administered to the animals for prophylactic treatment against bacterial disease. They were also treated for ecto and endoparasite using Ivermectin® (1 ml/10 kg). The four experimental diets (Table 1) were Control (no garlic and/or ginger powder), gap (Garlic inclusion: 2.5 g/kg diet inclusion), gip (Ginger inclusion: 2.5 g/kg diet) GGP (garlic: 1.25 g/kg diet + ginger: 1.25 g/kg diet). The dosage of ginger adopted for this experiment was as recommended by Muhammad *et al*. (2016). Levels of garlic powder adopted were to reflect the amount of ginger used in the study.The experiment lasted for 91 days consisting of 84 days for feeding trial and seven days for digestibility trial. All animal management protocols were approved by the Department of Animal Production, Federal University of Agriculture, Makurdi, Nigeria(CAS/ANP/2017/2018/10).

Table 1: Gross composition of experimental diets

	[1]Treatment Diets			
Ingredient	*Control*	*Gap*	*Gip*	*GGP*
Maize offal	45	45	45	45
Palm kernel cake	30	30	30	30
Soybean meal	10	10	10	10
Rice offal	10	10	10	10
Bone meal	3.5	3.5	3.5	3.5
Mineral premix	0.5	0.5	0.5	0.5
Salt	1	1	1	1
Garlic	-	0.25	-	0.125
Ginger	-	-	0.25	0.125
Total	100	100	100	100
[2]Determined analysis				
Dry matter	84.09	85.01	85.71	85.34
Crude protein	16.58	17.18	16.65	16.98
Ether extract	17.20	18.00	17.63	17.89
Ash	6.69	6.97	6.68	6.83
ADF	38.96	36.76	37.31	36.98
NDF	47.23	45.43	46.52	46.12

[1] Control (no garlic and/or ginger powder), gap (Garlic inclusion: 2.5 g/kg diet inclusion), gip (Ginger inclusion: 2.5 g/kg diet) GGP (garlic: 1.25 g/kg diet + ginger: 1.25 g/kg diet).
[2]ADF (acid detergent fiber), NDF (Neutral detergent fiber)

Data collection

Growth performance

The initial body weight of the sheep was determined at the commencement of the experiment with the aid of a digital weighing scale. A change in the weight of the sheep was obtained weekly. Forage and concentrateintakes were determined daily. The feed conversion ratio was calculated as the ratio of feed intake and weight gain

Weight gain (kg) = Final weight – Initial weight

Feed Intake (Kg)- Feed offered – Feed left over

$$FCR = \frac{\text{Total feed intake}}{\text{Total weight gain}}$$

Rumen ecology

Rumen samples were collected six hours post-feeding from the animals 84 days of supplementation using a suction tube. The samples were immediately measured for ph using a portable ph meter (Universal PH Test Kit – Digital PH Meter®) and were thereafter filtered with four-layer cheesecloth and subsamples were divided into two portions. The first portion was used to analyze for total volatile fatty acid (VFA) and the proportions of acetate, propionate, and butyrate as illustrated by Samuel *et al*. (1997). The samples were centrifuged at 3,000 xg for 10 min; they were allowed to settle and decanted. The decant was titrated with 0.1 M of sodium hydroxide (4/1000 $gml^{-1}H2O$) solution each with 2 – 3 drops of phenophtaline (1/100 gml^{-1}ethanol) as the indicator. Determination of the various fractions was as enumerated below:

Acetate = (Titre Value × 0.1 × 0.06 × 100) / 5

Propionate = (Titre Value × 0.1 × 0.04 × 100) / 5

Butyrate = (Titre Value × 0.1 × 0.006 × 100) / 5

Total volatile fatty acids = (Titre Value × 0.1 × 0.09 × 100) / 5

The second portion of the rumen filtrate was used for microbial count and identification. Protozoa count was obtained by direct observation using a microscope at 10× magnification (Dehority, 1984). Colony-forming units/ml (CFU/ml) of both bacterial and fungi were obtained with the pour plate technique using nutrient algae (NA) and potato dextrose agar (PDA), respectively. The plates were then incubated for 24 hours at 37◦C. All colonies appearing at the end of the incubation period were counted using a digital illuminated colony counter. Colonies grown on nutrient agar plates were suspected to be either gram-positive or gram-negative thus; all colonies found on each plate were used for gram staining as described by Chessbrough (2005). Colonies grown on the PDA were further incubated for three days after the first 24 hrs to check for morphology and isolation of fungi.

Apparent digestibility trial

By the end of the 84 days feeding trial, the animals were moved into metabolic cages for faecal collection. They were allowed four days to acclimatize; thereafter faecal samples were collected from each of the animals for three days daily in the morning and afternoon. Faeces were collected from wire-mesh nets placed under the floor of metabolism crates. Collected faecal samples were weighed daily then oven-dried at 65 ^{0}C for 48 hrs and ground to pass through a 1-mm screen and bulked on a replicate basis, and stored in an airtight container for chemical analysis.

Chemical analysis

The proximate composition (dry matter, crude protein, ether extract, ash) of the experimental diets and faeces were determined according to AOAC (2005) and fiber fractions (NDF and ADF) by the method of Van Soest *et al.* (1991).

Statistical analysis

Data on daily weight change, feed intake, feed conversion ratio, rumen ph, total volatile fatty acids, and their proportions, methane, microbial count, and nutrient

utilization were analyzed using a one-way analysis of variance as contained in the general linear model's procedures of SPSS (version 23). Significant differences among treatment mean where applicable were separated using the GLM procedure of SPSS. Probability significance was declared at $P \leq 0.05$.

Results

Growth performance of sheep fed diet containing garlic, ginger and their combination

The growth performance characteristics of sheep supplemented concentrate diet containing garlic and ginger powder and their combination is presented in Table 2. Daily weight change increased ($p<0.05$) in the herb combination group (GGP) compared to the control group. The gap and gip groups had comparative similar ($p>0.05$) values to both the control and GGP groups. Daily concentrate intake, forage intake, and feed conversion ratio were not affected ($p>0.05$) by the inclusion of garlic or ginger powder and their combination.

Rumen ph and metabolites of sheep fed diet containing garlic, ginger and their combination

The result of rumen metabolites of sheep on concentrate diet containing garlic and ginger and their combination is shown in Table 3. Total volatile fatty acid (tvfas) increased ($p<0.05$) in the gip and GGP groups. Highest ($p<0.05$) tvfas were observed in the gip group with the least ($p<0.05$) value found in the control group. The resulting pattern was the same for acetate, propionate, and butyrate. Herbal supplementation increased ($p<0.05$) the amount of the proportions of fatty acids with highest ($p<0.05$) concentrations recorded in the gip group, while the least ($p<0.05$) concentrations were observed in the control group. The result of the fatty acids and the various proportions in the gap group was similar ($p>0.05$) to the control group. However, ph and the ratio of acetate and propionate were not affected ($p>0.05$) by the inclusion of the herbs.

Rumen bacteria count of sheep fed diet containing garlic, ginger and their combination

Table 4 shows the rumen microbial count of sheep on diet containing garlic and ginger powder and their combination. Supplementation of herbal mixture gave the highest ($p<0.05$) bacteria count when compared to other groups. Least ($p<0.05$) comparative bacteria count was observed in control and gap groups. Supplementation with herbs increased ($p<0.05$) gram-negative bacteria numbers with comparative higher values obtained in all herbal supplemented groups compared to control, although values of gram-negative bacteria in gap and gip were similar to control group. Fungi, protozoa and gram-positive bacteria count were not affected ($p>0.05$) by the supplementation of garlic, ginger, or their combination.

Fungi isolated from the rumen of sheep fed diet containing garlic, ginger and their combination

The result of fungi isolates from the rumen of sheep on diet containing garlic and ginger herbs and their combination is presented in Table 5. Three different fungi species were isolated from the rumen of the sheep and counted. Supplementation of ginger powder decreased ($p<0.05$) *Rhizopus spp*. Isolated when compared to its combination with the combination of garlic and ginger. There were comparable values ($p>0.05$) of *Rhizopus spp*. In the control, garlic, and ginger powder groups. The isolates of *Penicillium spp*.and *Aspergillus spp.* Were not affected ($p>0.05$) by supplementation of the herbs.

Apparent nutrient digestibility of sheep fed diet containing garlic, ginger and their combination

The result of apparent nutrient digestibility of sheep on diet containing herbs and their mixture is as shown in Table 6. The herbs

Table 2: Growth performance parameters of sheep fed diet containing garlic and ginger

	[1]Treatment diets				
Parameter	*Control*	*Gap*	*Gip*	*GGP*	[2]SEM
Initial weight (kg)	16.17	15.49	15.49	14.55	0.57
Final weight (kg)	22.31	22.87	23.65	23.39	0.40
Daily weight gain (g)	91.29^{b}	105.39^{ab}	109.42^{a}	126.28^{a}	5.04
Daily forage intake (g)	677.70	674.95	675.37	675.85	0.94
Daily concentrate intake (g)	493.71	477.50	477.36	488.88	3.17
Total daily feed intake (g)	1171.41	1152.44	1152.73	1164.73	3.74
Feed conversion ratio	14.50	10.98	10.62	9.25	0.92

[A,b] Means with different superscript along the row differ ($p<0.05$)
[1] Control (no garlic and/or ginger powder), gap (Garlic inclusion: 2.5 g/kg diet inclusion), gip (Ginger inclusion: 2.5 g/kg diet) GGP (garlic: 1.25 g/kg diet + ginger: 1.25 g/kg diet).
[2]SEM (standard error of mean)

Table 3: Rumen metabolites of Sheep fed diets containing garlic and ginger powder

	[2]Treatment diets				
[1]Parameter	*Control*	*Gap*	*Gip*	*GGP*	[3]SEM
Ph	5.70	5.94	5.90	5.97	0.08
Tvfas(mmol/L)	5.50^{c}	6.05^{bc}	7.18^{a}	6.97^{ab}	0.21
Acetate (mmol/L)	3.67^{c}	4.02^{bc}	4.79^{a}	4.64^{ab}	0.14
Propionate (mmol/L)	2.44^{c}	2.68^{bc}	3.19^{a}	3.10^{ab}	0.09
Butyrate (mmol/L)	0.37^{c}	0.40^{bc}	0.48^{a}	0.46^{ab}	0.01
A:P	1.50	1.50	1.50	1.50	0.007

[A,b,c]means with different superscript along the row differ ($p<0.05$)
[1]tvfas (total volatile fatty acids), A:P (acetate and propionate ratio)
[2] Control (no garlic and/or ginger powder), gap (Garlic inclusion: 2.5 g/kg diet inclusion), gip (Ginger inclusion: 2.5 g/kg diet) GGP (garlic: 1.25 g/kg diet + ginger: 1.25 g/kg diet).
[3]SEM (standard error of the mean)

Table 4: Rumen Microbial count of Sheep fed diets containing garlic and ginger powder

	[1]Treatment diets				
Parameter	*Control*	*Gap*	*Gip*	*GGP*	[2]SEM
Bacteria ($\times10^{7}$ cfu/ml)	2.27^{b}	2.73^{b}	2.93^{ab}	3.58^{a}	0.13
Fungi ($\times10^{3}$ cfu/ml)	1.30	1.02	0.88	0.70	0.09
Protozoa (cells/ml)	16.00	19.33	23.00	16.00	1.75
Gram+ bacteria ($\times10^{7}$ cfu/ml)	4.83	1.33	3.00	0.00	0.80
Gram- bacteria ($\times10^{7}$ cfu/ml)	17.83^{b}	26.00^{ab}	26.33^{ab}	35.75^{a}	1.76

[A,b]means with different superscript along the row differ ($p<0.05$)
[1] Control (no garlic and/or ginger powder), gap (Garlic inclusion: 2.5 g/kg diet inclusion), gip (Ginger inclusion: 2.5 g/kg diet) GGP (garlic: 1.25 g/kg diet + ginger: 1.25 g/kg diet).
[2]SEM (standard error of mean)

Table 5: Fungi Isolates from the rumen of sheep fed diets containing garlic and ginger powder

	[1]Treatment diets				
Parameter	*Control*	*Gap*	*Gip*	*GGP*	[2]SEM
Penicillum spp ($\times10^{3}$ cfu/ml)	0.50	0.33	0.33	0.00	0.10
Rhizopus spp. ($\times10^{3}$ cfu/ml)	0.50^{ab}	0.33^{ab}	0.17^{b}	1.00^{a}	0.11
Aspergillus spp.($\times10^{3}$ cfu/ml)	0.00	0.33	0.50	0.00	0.09

[A,b]means with different superscript along the row differ ($p<0.05$)
[1] Control (no garlic and/or ginger powder), gap (Garlic inclusion: 2.5 g/kg diet inclusion), gip (Ginger inclusion: 2.5 g/kg diet) GGP (garlic: 1.25 g/kg diet + ginger: 1.25 g/kg diet).
[2]SEM (standard error of mean)

Table 6: Apparent nutrient digestibility of sheep on concentrate diet containing garlic and ginger powder

	[2]Treatment diets				
[1]Parameter	*Control*	*Gap*	*Gip*	*GGP*	[3]SEM
Dry matter	67.99[c]	72.41[a]	68.24[bc]	68.86[b]	0.54
Crude protein	60.89	66.38	65.10	67.01	1.07
Ether extract	61.44	63.46	61.19	64.68	0.65
Ash	55.67[b]	62.21[a]	60.45[a]	62.45[a]	0.95
NDF	59.21[b]	61.12[b]	68.37[a]	67.91[a]	1.50
ADF	59.21[b]	66.16[a]	68.26[a]	67.97[a]	1.28

[A,b,c]means with different superscript along the row differ ($p<0.05$)

[1]ADF (acid detergent fibre), NDF (Neutral detergent fibre)

[2] Control (no garlic and/or ginger powder), gap (Garlic inclusion: 2.5 g/kg diet inclusion), gip (Ginger inclusion: 2.5 g/kg diet) GGP (garlic: 1.25 g/kg diet + ginger: 1.25 g/kg diet).

[3]SEM (standard error of mean)

and their mixture influenced ($p<0.05$) the digestibilities of dry matter (DM), ash, neutral detergent fiber (NDF) and acid detergent fiber (ADF). Dry matter digestibility was improved ($p<0.05$) in the herbal groups with the highest ($p<0.05$) dry matter digestibility observed in the gap group. Least ($p<0.05$) DM digestibility was observed in the control group, although this was similar ($p>0.05$) to the gip group. Comparatively higher ($p<0.05$) values of ash digestibility were observed in the herb groups compared to the least value ($p<0.05$) found in the control group. The NDF digestibility was comparatively higher ($p<0.05$) in gip and GGP groups and reduced ($p<0.05$) in the control and gap groups which had comparative least values. The ADF Digestibility was comparatively higher ($p<0.05$) in all herb groups and reduced ($p<0.05$) in the control group with the least ADF digestibility. Crude protein and ash digestibilities were not influenced ($p>0.05$) by supplementation of herbs.

Discussion

Growth performance

Parameters of growth such as daily weight changes, feed intake, and feed conversion ratio could be used to judge the performance of the animal. Improved daily changes in sheep in the herbal combination group (GGP) is evident of the additive effect of the two herbs when used at lower amounts. The higher amount of ginger powder inclusion decreased weight in sheep while the weight of goats remained unchanged with an increasing amount of garlic powder (Muhammad *et al*., 2016; Ikyume *et al*., 2017). Feed conversion ratio (FCR) was increased by about 36% in the herb combination group (GGP) compared to about 24% and 28% for garlic (gap) and ginger (gip) powder groups, respectively. The non-significant increases in FCR in this current study are consistent with those of other results reported in sheep and goat on ginger and garlic powder, respectively (Muhammad *et al*., 2016; Ikyume *et al*., 2017).

Rumen ecology

The rumen ph is a factor that affects rumen health, microbial stability and shift, and a prerequisite for optimal microbial proliferation. The ph could be used to predict the type of diet fed to animals, and its degree of increase or decrease can predict the rate of fermentation. The optimal ph for fiber digestion is between a range of 5.8 to 6.0 (Kolver and De Veth, 2002). Although not significant for the herb groups, the ph of the control was below the recommended range. The diet offered to the animals may have been the reason for the lower ph. Garlic or ginger powder and/or their combination, however, were able to

marginally raise the ph in the rumen to levels recommended for fiber digestion. Wanapat *et al.* (2013) have reported an increase in ph in beef cattle supplemented with a combination of garlic, lemon, and peppermint. Zhang *et al.* (2011) have also reported a marginal increase in ph in sheep. On the contrary, ph was reduced in goats and lamb supplemented garlic products (Hodjatpan *et al.,*2010; Ikyume *et al.,* 2017). The slight increase in the ph of the rumen may have also been responsible for significant increases in the concentration of total volatile fatty acids and the various proportions. Lower ph leads to a decrease in fibrolytic activity and this is caused by microbe's inability to maintain the ph inside their cell (Chiba, 2014). Herbs have antimicrobial properties and can modify the rumen to improve energy or protein use in the rumen (Kamel, 2001). An increase in volatile fatty acids and its proportions caused by herbal supplementation in this studyindicate the efficiency of nutrient digestion.Under *in vitro* conditions, garlic and ginger separately improved the concentration of short-chain fatty acids (Tag El-Din *et al.,* 2012; Ikyume *et al.,* 2018). On the contrary, garlic powder supplementation did not influence the proportions of tfvas, acetate, propionate, and butyrate in goats (Ikyume *et al.,* 2017). Also, tvfas concentration was reduced in sheep on ginger while the proportions of acetate, propionate, and butyrate were not affected (Zhang *et al.,* 2011). The increase in concentrations of tvfas, acetate, propionate, and butyrate in this study as seen in the ginger powder group and with combination with garlic is to show that the use of ginger and in combination with garlic at levels used in this study would likely increase microbial activity and diet fermentability.Higher propionate concentrations would lead to an increased glucogenic potential of the diet (Zhu *et al.,* 2017). The feeding of ginger or in combination with garlic will increase glucogenic activities in the rumen when compared to control and garlic alone. Differences between this present result and other researchers could be specie and/or dose and duration dependent. Zhang *et al*. (2011) suggested that the effect of ginger powder in sheep diet decreased the total VFA concentration disappeared thereafter after 20 days of feeding and reported that ruminal microbes may have adapted after 20 days and built up a tolerance to it. Increased bacteria count in the GGP group with a similar value in gip group is consistent with the report of Muhammad *et al.* (2016) that, ginger powder increased bacteria count but not beyond the level of 2.5 g/kg as used in this study. The non-significant effect of the gap group with control is consistent with the report of Ikyume *et al.* (2018) for goats. However, the complementary effect of both ginger and garlic in this study gave an optimum increase in bacteria count. The pattern in bacteria count was also observed in the gram-negative strains of bacteria in this current study. A ph lower than 5.8 has been reported to leadto a decline in the population of Bacteroidetes which are Gram-negative (Cardo, 2015), which may have explained a reduction in gram-negative bacteria in the control group which had a ph of 5.70. Such action in reducing gram-negative bacteria will lead to a shift of microbes to Gram-positive lactic acid producers in the rumen (Ososanya *et al.,* 2013; Petri *et al.,* 2013). Such a shift to gram-positive bacteria was seen in this current study even though it was not significant. Besides, Ikyume *et al.* (2017) have reported that gram-negative bacteria are less susceptible to inhibition by garlic powder, which explains the more numbers found in the herb groups. The less susceptibility to inhibition to herbs by gram-negative bacteria may be explained by the presence of an outer lipid membrane

present in gram-negative but not gram-positive bacteria. Besides, evaluation of anti-bacterial properties of garlic and ginger on about five strains of gram-negative and two strains of gram-positive bacteria indicated all isolates except *Enterobacter sp*. And *Klebsiella sp.* (Gram-negative bacteria) were susceptible to crude extract of both garlic and ginger (Karuppiah and Rajaram, 2012). This is to say that the combined effect of garlic and ginger at levels used in this study will provide a modulatory effect on a wide range of bacteria, which can be a strategy to modify the rumen environment to improve the efficiency of nutrient utilization. Various fungi species have been used for solid-state fermentation to improve nutrient digestibility in livestock (Thakur *et al.,* 2015; Mahalakshmi and Jayalakshmi, 2016). This is because fungi are involved in cross-feeding; they release free sugars, which in addition to several of their normal metabolites (except acetate), serve as energy sources for other bacterial species. Besides, Secondary metabolites of fungi are used as medicines, such as antibiotics and anticoagulants. Improved presence of *Rhizopus sp.* In the GGP group may be beneficial to the animals' health since they are useful for bio-sorption (passive adsorption of chemical contaminants by an organism) of heavy metals (Petruzzello, 2013).

Nutrient digestibility

Improved digestibility of dry matter, ash, NF, and ADF in the herb-supplemented groups may have been because of the rumen modifier effect of ginger or garlic and their combination as seen in the rumen ecology. The improved dry matter digestibility is not consistent with the result for garlic in beef cattle and goats (Wanapat *et al.,* 2013; Ikyume *et al.,* 2017). The difference could be the species of animals and the amount of garlic used in the different reports. Herbs such as ginger and garlic are said to be digestion stimulants (Janz *et al.,* 2007, Srinivasan, 2005). This action to stimulate digestion may have been responsible for increased dry matter, ash, and fiber digestibility. Garlic and ginger are antioxidants (Chung, 2006; Danwilai *et al.,* 2017), and according to Vásquez-Anon and Jenkinst (2007), antioxidant compounds can ameliorate the toxic effect of excessive unsaturated fatty acids in the rumen and this can improve rumen efficiency. Accumulation of unsaturated fatty acids in the rumen may cause irregular microbial digestion (NRC, 2001). Antioxidant properties of garlic and ginger that may lead to ameliorating the effect of unsaturated fatty acids in the rumen will need to be investigated further.

Conclusion

The study showed that the effect of feeding garlic and ginger to sheep to manipulate rumen fermentation, microbial populations, and improve nutrient digestibility and growth performance can be better enhanced if the two are combined at lower amounts. The combination of 1.25 g/kg of garlic and 1.25 g/kg of ginger (total 2.5 g/kg) gave a better rumen modifier effect than feeding garlic and ginger at 2.5 g/kg singly. Further research can vary the levels of combination.

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Declaration of interest

The authors declare that there was no competing interest in the course of the work.

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