Effect of varying levels of garlic (*Allium sativum*) powder on growth, apparent nutrient digestibility, rumen ecology, blood profile and cost analysis of feeding West African Dwarf goats

Ikyume[1*], T.T., Sowande[2], O.S., Dele[3], P.A., Yusuf[2], A.O., Monday[2], S., Egunjobi[2], O.K. and Fatoba[2], O.

[1]Department of Animal Production, College of Animal Science, Federal University of Agriculture, Makurdi, Benue State, Nigeria, [2]Department of Animal Production and Health, [3]Department of Pasture and Range Management, College of Animal Science and Livestock Production, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria.

*Corresponding author: Ikyume.timothy@uam.edu.ng

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Abstract

The study was designed to investigate the feeding effect of garlic powder supplementation on growth performance, apparent nutrient digestibility, rumen fermentation, rumen micro organisms and blood profile of West African Dwarf (WAD) goats. For this purpose, 20 WAD bucks with mean average weight of 6.92±0.02 kg were balanced for weight and assigned to 4 treatment groups, i.e., Control, GP0.5 (0.5%/100 kg garlic powder supplementation), GP1.0 (1.0%/100 kg garlic powder supplementation), GP1.5 (1.5%/100 kg garlic powder supplementation). Animals were managed in individual pens and fed *Panicum maximum* as basal diet and concentrate (Treatment diet) at ratio 70:30 for 98 d after 21 d period of acclimatization. Results of this study showed that final weight, daily weight gain, concentrate intake, grass intake, total feed intake and feed conversion ratio were not significantly (p>0.05) affected by inclusion of garlic powder up to 1.5%. Crude protein digestibility significantly (p<0.05) decreased with increased garlic powder supplementation. DM, CF, EE, Ash, NDF and ADF were not significantly (p>0.05) affected by garlic powder supplementation. Rumen pH and NH_3-N were significantly (p<0.05) affected by garlic powder supplementation. TVFA, acetate (A), butyrate (B) propionate (P) and A:P ratio were not significantly (p>0.05) affected by garlic powder supplementation. Garlic powder had inhibition effect on gram positive bacteria. Also haematological parameters measured in this study were not significantly (p>0.05) different with garlic powder supplementation. Total protein (TP), glucose and albumin decreased significantly (p<0.05) with higher levels of garlic powder supplementation. Findings of this present study reveal that garlic powder supplementation up to 1.5% in concentrate diet did not exert any adverse effect on performance of WAD goats.

Key words: Garlic powder, WAD goats, growth performance, apparent digestibility, blood profile, rumen fermentation,

Introduction

Exorbitant cost of cattle production has encouraged the production of small ruminants (sheep and goats) which cost less in terms of feeding and other management practices (Taiwo *et al*. 2005). Goats are prolific breeders and its unique ability to kid twice in every 14 mo and also produce 7 female kids in 8 y cannot be achieved either by cow or buffalo (Gopalakrishman *et al.*, 1991). Recently, attention has been paid to small ruminants in developing countries like Nigeria as the small ruminants advantages are becoming more understood than ever before, particularly for their ability to produce meat, milk, skin and wool even in hostile environment (Konlan *et al*., 2012). Therefore there is a continued search for increased efficiency in ruminant production given its importance to the society.

Ruminants contribute to global warming by releasing greenhouse gas emissions through normal rumen fermentation. It is reported that ruminants fed low quality feed could release large amount of methane (Iqbal and Hashim, 2014).

Plant herbs such as garlic (*Allium sativum)* are widely used as antibacterial agents to maintain the microbial ecosystem of the gastro-intestinal track especially in tropical regions in order to improve their productivity. These herbs and plant extracts have been shown to manipulate ruminal fermentation and improve nutrient utilization in ruminants (Busquet *et al*., 2005; Patral *et al*., 2006; Wanapat *et al*., 2008a). Garlic has been studied as aqueous or ethanol extracts or as dried powder (Shin and Kim, 2004) as it contains high level of organosulfur compounds such as allicin, ajoene, s-allyl cysteine, dially disulphide, and s-methylcysteine sulfoxide (Chi *et al*., 1982). In vitro research on use of garlic to reduce methane production from ruminants showed a promising result (Busquet *et al*., 2005; Adewunmi, 2008; Zafarian and Manafi, 2013). All these results must be validated under *in vivo* studies as Wolin *et al.* (1997) has stated that any method to suppress methane production in ruminants has tendency to reduce their performance. Also the fact that some herbs and spices also exhibit antimicrobial properties suggests that phytogenic feed additives may pose similar risks to producers and meat consumers. Similarly, potential overdose that may be harmful to the animals is possible. Because there is little information on the optimum levels of garlic as feed supplement on practical on-farm options for significantly improving productivity, this research seek to explore the efficacy of feeding garlic powder on performance of WAD goats with actual doses.

Materials and Methods

Experimental site

The feeding trial was carried out at the Small Ruminant Experimental Unit, Directorate of University Farms (DUFARMS), Federal University of Agriculture Abeokuta, Nigeria and the laboratory analyses was conducted at the Animal Nutrition as well as Microbiology Departmental Laboratory at Federal University of Agriculture, Abeokuta, Ogun State, Nigeria.

Experimental design and procedure

A total of 20 West African Dwarf (WAD) bucks between 6-7 mo with live weight range of 5-8 kg were sourced from a small holder goat farm at Camp, Abeokuta for this study . They were housed individually in an experimental pen with aluminium roofing sheet and raised slatted floor. The 20 bucks were allotted to 4 treatment groups containing 5 animals per treatment for a 98-day trial comprising of 84-d period for collection of performance records and 14 d for digestibility trial in a completely randomized design. The animals were maintained on forage (*Panicum maximum*) and concentrate supplement during the research at a ratio 70:30. The goats were balanced for weight and allotted to 4 dietary treatments (Table 1): Control (control 0% garlic powder (GP)), GP0.5 (0.5% garlic powder), GP1.0 (1% garlic powder) and GP1.5 (1.5% garlic powder).

Table 1: Ingredient composition (%) of experimental concentrate diets fed to WAD goats

Ingredients	Control	[1]GP0.5	[2]GP1.0	[3]GP1.5
Palm kernel cake	32.00	32.00	32.00	32.00
Wheat offal	34.00	34.00	34.00	34.00
Maize	30.00	29.50	29.00	28.50
Bone meal	3.00	3.00	3.00	3.00
Salt	0.50	0.50	0.50	0.50
Vitamin premix	0.50	0.50	0.50	0.50
Garlic powder	0.00	0.50	1.00	1.50
Total	100	100	100	100
<u>Determined analysis</u>				
Crude protein	14.01	13.13	12.96	12.25
Neutral detergent fibre	41.68	56.30	59.58	63.37
Acid detergent fibre	40.23	43.56	48.65	51.34

[1]GP0.5- Garlic (*A. sativum*) powder at 0.5% level of inclusion
[2]GP1.0- Garlic (*A. sativum*) powder at 1% level of inclusion
[3]GP1.5- Garlic (*A. sativum*) powder at 1.5% level of inclusion

Data collection - Weight change and feed intake

Weight change of the goats was obtained on weekly basis by determining the average weight change of the goats per treatment for the week and subtracting from the previous week. Feed intake was determined by subtracting feed left over from feed offered to the animals. Feed conversion ratio (FCR) was determined by calculating the ratio of total feed consumed in kg to total weight gain in kg per treatment.

Haematological parameters and serum biochemical constituents

Blood samples were collected from 3 replicates per treatment at the end of the study for haematological and serum analysis. Blood sample for hematological indices were emptied into sample bottles containing ethylene tetra acetic acid (EDTA) to prevent blood clotting while those for serum biochemistry were collected without anti-coagulant. Red blood cell (RBC) and white blood cell (WBC) were measured using the improved Neubauer haemocytometer after appropriate dilution (Schalms *et al.,* 1985). Packed cell volume (PCV) and hemoglobin (Hb) were determined using microhaematocrit method and cyanmethamoglobin method, respectively. Serum total protein concentration was determined by Biuret colorimetric reaction (Burties *et al.*,1999). Total cholesterol was also determined according to the method of Friedwald *et al*. (1972) and serum albumin concentration was determined as described by Douman (1971) while the serum globulin was determined by subtracting the serum albumin from the serum total protein.

Apparent nutrient digestibility

During the last 14 days of the experiment, the animals were moved to metabolic cages for collection of faeces during which time they were restricted to 90% of the previous voluntary feed intake of *Panicum maximum* (basal diet) and supplemented with concentrate at 2% of BW daily to ensure total feed intake. They were allowed periods of 7 d to acclimatize thereafter faecal samples were collected from each of the animals for 7 d on a daily basis in the morning and afternoon. Collected faecal samples were weighed daily then oven dried to a constant weight and bulked by replicate basis, ground and stored in air tight containers for proximate analysis using standard methods of A.O.A.C (1995) for DM, ash, EE, ADF and NDF by method of Van Soest *et al.,* (1991).

Rumen fermentation analysis

Rumen fluid was collected from 4 animals per treatment at the end of the experiment 6 h post feeding. Approximately 60 ml of rumen fluid for each replicate were taken from the middle part of the rumen using a suction tube that was passed through the esophagus. Rumen fluid was immediately measured for pH using a portable pH meter. Rumen samples were filtered through 4-layer cheesecloth and subsamples were transferred into plastic bottle to which 5 ml of 1M H_2SO_4 had been added to stop microbial fermentation and then centrifuged at 3,000 xg for 10 min. About 25 ml of the supernatant was then collected and analyzed for NH_3-N according to method of A. O. A. C (1995). Another portion was used to determine total volatile fatty acid (TVFA) and its various constituents were determined according to Samuel *et al.* (1989).

Cost analysis of feeding varying inclusion levels of garlic powder

The prevailing market prices of the ingredients at the time of the study were used to calculate the cost of 1 kg feed consumed and the cost of 1 kg feed consumed/weight gain. The economic performance was determined by computing the feed cost/kg (naira/kg) as follows:

Cost of total feed intake
= Total feed intake x Feed cost per kg

Feed cost/kg weight gain
= Cost of total feed intake/Total weight gain (kg)

Chemical analysis

The proximate composition of the feed and faecal samples was determined according to AOAC (1995) and fibre fractions by the method of Van Soest *et al.* (1991).

Statistical analysis

The data generated were subjected to analysis of variance using SAS (2000) statistical software. Significantly different means were separated using Duncan's Multiple Range Test at ($P<0.05$) level of probability.

Results and Discussion

Increasing levels of garlic powder had no significant ($p>0.05$) effect on final mean weight, total weight gain, daily weight gain, concentrate intake, grass intake, total feed intake and feed conversion ratio (Table 2). Although the growth performance characteristics were not different statistically, goats fed the control diet had numerically higher values of total weight gain (4.08 kg), and daily weight gain (48.52 g). Total and daily weight gain numerically decreased with increasing amount of garlic powder inclusion. This showed that higher amount of garlic powder in diets of West African Dwarf goats had the tendency to reduce the growth performance. This could be a result of the antimicrobial properties of garlic which could lead to suppressed rumen digestion. Wolin *et al.* (1997) stated that any method to suppress methane production (hydrogen sink) must be accompanied by a method to convert the resulting accumulated hydrogen, a waste product of rumen fermentation. Result is consistent with findings of Hassan and

Sherief (2013) when addition of garlic in diet of buffalo calves did not have any significant effect on the total weight gain. Tatara *et al.* (2008) also reported that garlic did not significantly affect growth rate though improved growth was observed.

Similar results from Bampidis *et al.* (2005) also indicated that weight gain was not significantly affected by dietary garlic bulb and husk supplementation in growing lambs compared to control. Garlic powder supplementation had no effect on dry matter intake (DMI). This is consistent with reports from Wanapat *et al*. (2013) that found no change in DMI when beef cow were fed garlic powder and other herb combination. Also, Benchaar *et al.* (2007) and Yang *et al.* (2007) found no effect in DMI when dairy cows were fed garlic oil and mixtures of essential oil compounds. DMI of this present study also agrees with reports of Rasoul *et al.* (2014) who found no significant effect in DMI when pre-partum Mahabadi goats were supplemented with raw garlic. Garlic powder supplementation in this study had no significant effect on the feed conversion ratio (FCR) of West WAD goats. This result is in agreement with reports by Strickland *et al*. (2009) who reported that inclusion of raw garlic in diet of Merino lambs aged 6 mo decreased the rate of feed conversion. However this result is in contrast with report by Gosh *et al.* (2010) who observed an increased feed conversion when Holstein cross calves were fed garlic extract at 250 mg/kg BW/day. The differences in FCR obtained in the current study and that of Gosh *et al.* (2010) could be attributed to the dosage and form of garlic utilized as well as species or breed of animal.

Table 2: Performance characteristics of West African Dwarf goats fed varying levels of garlic (*Allium sativum*) powder

Parameter	Control	[1]GP0.5	[2]GP1.0	[3]GP1.5	SEM
Initial weight (kg)	6.92	6.90	6.90	6.92	0.28
Final weight (kg)	11.00	10.93	10.77	10.63	0.29
Total weight gain (kg)	4.08	4.04	3.87	3.71	0.10
Daily weight gain (g)	48.52	48.07	46.07	44.21	1.22
Concentrate intake (kg)	12.18	12.21	12.16	12.51	0.22
Grass intake (kg)	33.71	32.19	31.81	33.48	0.44
Total feed intake (kg)	45.69	44.40	43.97	45.99	0.60
Feed conversion ratio	11.30	11.10	11.50	12.50	0.29
Mortality (%)	0.00	0.00	0.00	0.00	0.00

[1]GP0.5- Garlic (*Allium sativum*) powder at 0.5% level of inclusion
[2]GP1.0- Garlic (*Allium sativum*) powder at 1% level of inclusion
[3]GP1.5- Garlic (*Allium sativum*) powder at 1.5% level of inclusion

All the parameters measured were not affected ($p>0.05$) by supplementation of garlic powder in diet except the crude protein which was significantly ($p<0.05$) influenced by the inclusion of garlic powder in diet of WAD goats (Table 3). The decrease in crude protein digestibility in this present study suggests that garlic powder inhibited protein digestibility. This could be good for the animals as protein is protected for utilization in the small intestine. The significantly decreased crude protein digestibility is consistent with Wanapat *et al*. (2013) when garlic was fed to beef cattle in combination with other plant herbs such as lemon grass and peppermint. Other reports by Wanapat *et al.* (2008a, b) also showed that supplementary action of garlic powder could decrease CP digestibility. In contrast, Ahmad *et al.* (2011) reported a slight increase, though not significant in CP digestibility when growing lambs were supplemented with garlic oil at 0.4 g/lamb/day. The differences observed for CP digestibility between this present study and others could be dose-dependent and the form in which garlic was utilized. The result of other parameters measured in this present study is consistent with several other researchers who reported that garlic and other plant herbs did not significantly affect apparent digestibility (Castellijos *et al.*, 2006; Hosoda *et al.*, 2006; Ahmad *et al.,* 2011; Wanapat *et al.,* 2013). Also, true digestibility of DM, NDF and ADF were not affected by garlic oil supplementation (Busquet *et al.*, 2005).

Table 3: Effects of varying levels of garlic powder supplementation on apparent nutrient digestibility of West African Dwarf goats

Parameters (%)	Control	[1]GP0.5	[2]GP1.0	[3]GP1.5	SEM
Dry matter	66.52	71.48	62.21	60.91	1.87
Crude protein	75.78[a]	68.70[b]	60.84[c]	56.95[c]	2.79
Crude fiber	68.19	75.43	67.68	66.65	1.81
Ether extract	74.16	80.59	73.56	67.43	2.15
Ash	60.32	60.42	57.67	54.64	1.58
NDF	60.94	61.48	67.27	69.67	1.91
ADF	58.44	60.89	65.65	61.42	1.85

[abc] Means with different superscript on the same row differ significantly ($p<0.05$)
[1]GP0.5- Garlic (*Allium sativum*) powder at 0.5% level of inclusion
[2]GP1.0- Garlic (*Allium sativum*) powder at 1% level of inclusion
[3]GP1.5- Garlic (*Allium sativum*) powder at 1.5% level of inclusion
NDF- Neutral detergent fibre
ADF- Acid detergent fibre

As presented in Table 4, the pH value and ammonia nitrogen content were significantly ($p<0.05$) different across treatment groups. Results recorded for ammonia nitrogen decreased significantly ($p<0.05$) across treatment groups, but not in a definite pattern. Total volatile fatty acid (TVFA), acetate, butyrate, propionate and A:P ratio were numerically higher in the control group but not significantly ($p<0.05$) different across the treatments. Results of rumen pH agree with findings by Zhi *et al.* (2012) who reported a decrease in rumen pH of goats through garlic oil infusion at 0.8 g/day. Hodjatpan *et al.* (2010) also reported a decrease in pH compared to control from 6.34 to 6.11 in sheep fed garlic oil at 420 mg/day. However, result from this present study is in contrast with report by Wanapat *et al.* (2013) who observed an increase in pH when beef cattle were supplemented with combination of garlic, peppermint and lemon grass. The contrast with this present study could be adjured to the herb combination effect. The decrease in NH_3-N concentration could be as a result of the effect of garlic exerting on protein digestibility. Wallace (2004) reported that NH_3-N formation is affected only at the last step of the breakdown sequence of protein that is the deamination of amino acids. In this study, the reduced NH_3-N concentration during fermentation suggested that garlic powder seemed to reduce the deamination which suggests the action of garlic powder to suppress dehydrogenases which is necessary for deamination when methane inhibitors are used (Hino and Russell, 1985). Also, increase in NH_3-N absorption by rumen epithelium could also cause a reduced NH_3-N concentration in the rumen. Reports have it that NH_3-N is regarded to be the most important nitrogen source for microbial protein synthesis in the rumen (Wanapat *et al.,* 2008). Chaves *et al.* (2011) also reported a numerical decrease in ruminal ammonia nitrogen (NH3-N) of growing lambs through administration of garlic oil. Other researchers have reported a decrease in ruminal NH_3-N concentration due to garlic supplementation (Kongmum *et al.,* 2010; Anassori *et al.,* 2011). In contrast, Yang *et al.* (2007) reported increased NH_3-N concentration in the rumen of lactating cows fed garlic oil. Reduced NH_3-N concentration in garlic powder group may affect microbial protein synthesis, as further study is needed to investigate the mechanism of reduced NH_3-N concentrations rations by garlic powder. The non-significant TVFA recorded in this present result is consistent with that of other researchers who did not observe a significant difference in supplementing garlic (Busquet *et al.,* 2005; Wanapat *et al.,* 2008b; Wanapat *et al.,* 2013).

Table 4: Effects of varying levels of garlic (*Allium sativum*) powder supplementation in diets of WAD goats on rumen fermentation parameters

Parameters	Control	[1]GP0.5	[2]GP1.0	[3]GP1.5	SEM
pH	6.50^{a}	6.40^{b}	6.36^{c}	6.33^{d}	0.02
NH_3-N (g/100 ml)	65.92^{a}	62.09^{ab}	44.65^{c}	51.88^{bc}	2.65
TVFA (Mm/100 mol)	1.52	1.47	1.31	1.28	0.05
VFAs (mol/100 mol)					
Acetate	0.79	0.98	0.87	0.86	0.06
Butyrate	0.10	0.10	0.09	0.09	0.00
Propionate	0.67	0.65	0.58	0.57	0.02
A:P ratio	1.16	1.50	1.50	1.50	0.08

[abc]Means with different superscript on the same row are differ significantly ($p<0.05$)
TVFA- Total volatile fatty acid
[1]GP0.5- Garlic (*Allium sativum*) powder at 0.5% level of inclusion
[2]GP1.0- Garlic (*Allium sativum*) powder at 1% level of inclusion
[3]GP1.5- Garlic (*Allium sativum*) powder at 1.5% level of inclusion
A: P- Acetate to propionate ratio

Results indicate that *Micrococcus acidophillus* and *Streptococcus spp*. which are Gram-positive bacteria were present in all treatment groups (Table 5). Other bacteria such as *Salmonella spp., Proteus spp. and Enterobacter spp.* which are Gram-negative were found in supplemented groups but not isolated from the control group. Gram-positive bacteria appeared to be more susceptible to inhibition by garlic powder supplementation. Ultee *et al*. (1999) reported that the activity of herbs affects electron transport, ion gradients, protein translocation, phosphorylation steps and other enzyme-dependent reactions, causing the affected bacteria to lose chemiosmotic control. This is due to the fact that while gram-negative bacteria were found in supplemented group, such could not be isolated in the control group. Davidson and Naidu (2000) reported that gram-positive bacteria appeared to be more susceptible to inhibition by plant essential oil compounds than did gram-negative bacteria. Results of this present study on bacteria species correspond with that of Wanapat *et al.* (2013) who indicated that garlic powder in combination with other herbs inhibitated gram-positive bacteria. The lack of effect of garlic powder on gram-negative bacteria can be attributed to the presence of outer membrane which gives them a strong impermeability barrier (Nikaido, 1994).

Table 5: Bacteria and fungi species isolated from rumen of WAD goats fed supplemental levels of garlic powder

Parameters	Control	[1]GP0.5	[2]GP1.0	[3]GP1.5
Bacteria	*Micrococcus acidiphillus,*	*Micrococuss acidiphilus,*	*Micrococcus acidophilus,*	*Micrococcus acidiphillus,*
	-	*Micrococcus leteus,*	*Micrococcus leteus,*	-
	Streptococcus spp.,	*Streptococcus spp.,*	*Streptococcus spp.,*	*Streptococcus spp.,*
	Bacillus cereus,	-	-	-
	Clostridium spp.	-	-	-
	-	*Bacillus subtilis,*	*Bacillus subtilis,*	*Bacillus subtilis,*
	-	*Salmonella spp.*	*Salmonella spp.,*	*Salmonella spp.,*
	-	-	*Proteus spp.*	-
	-	-	-	*Enterobacter spp.*
Fungi	*Aspergillus flavus*	*Aspergillus flavus,*	*Aspergillus flavus,*	*Aspergillus flavus,*
	Mucor spp.,	*Mucor spp.,*	*Mucor spp.,*	*Mucor spp.,*
	Aspergillus fumigates,	*Aspergillus fumigates,*	-	-
	Candida spp.	-	-	-
	Penicillium spp.	-	-	-
	-	*Aspergillus oryzae*	-	-
	-	-	*Aspergillus niger*	*Aspergillus niger,*
	-	-	*Rhizopus spp.*	-
	-	-	-	*Trichoderma spp.,*

[1]GP0.5- Garlic (*Allium sativum*) powder at 0.5% level of inclusion
[2]GP1.0- Garlic (*Allium sativum*) powder at 1% level of inclusion
[3]GP1.5- Garlic (*Allium sativum*) powder at 1.5% level of inclusion

The results as presented in Table 6 indicated that goats supplemented with garlic powder recorded significantly ($p<0.05$) higher value (0.67 %) for eosinophil with the control and GP1.0 groups having the least value (0.00%). Supplementation with varying levels of garlic powder did not significantly ($p>0.05$) affect other haematological parameters considered. The non significant results for packed cell volume (PCV), haemoglobin (Hb), red blood cell (RBC), white blood cell (WBC) agree with of Adewumi, 2008; Yang *et al.*, 2007 and Craige, 1999. The values observed in this present study are within normal range values as reported by Merck's Veterinary Manual (2012). However there was a significant difference in the eosinophil value recorded in this present work even though same value of $p < 0.01$ was observed in both control and GP1.0 groups which suggests the significant difference was not due to the treatment effect but probably individual animal effect.

Table 6: Effects of varying levels of garlic (*Allium sativum*) powder diet supplementation on haematological parameters of WAD goats

Parameters	*Range	Control	[1]GP 0.5	[2]GP 1.0	[3]GP 1.5	SEM
PCV (%)	22-38	30.67	31.00	27.33	29.00	0.92
Haemoglobin(g/dl)	8-12	10.57	10.33	9.33	9.53	0.32
RBC (10^{12}/L)	8-18	9.77	10.13	9.43	9.93	0.16
WBC(10^{9}/L)	4-13	10.10	10.37	9.77	10.13	0.37
Neutrophil (%)	30-48	33.00	33.00	33.00	32.67	0.76
Lymphocyte (%)	50-70	64.00	63.67	64.00	64.67	0.99
Eosinophil (%)	1-8	0.00^{c}	0.67^{ab}	0.00^{c}	0.67^{ab}	0.15
Basophil (%)	0-1	0.33	1.00	1.00	1.00	0.21
Monocytes (%)	0-4	2.00	1.67	1.00	1.67	0.23

[abc]Means with different superscript on the same row are significant ($p<0.05$)
[1]GP0.5- Garlic (*Allium sativum*) powder at 0.5% level of inclusion
[2]GP1.0- Garlic (*Allium sativum*) powder at 1% level of inclusion
[3]GP1.5- Garlic (*Allium sativum*) powder at 1.5% level of inclusion
MCV- Mean corpuscular volume, MCH- Mean corpuscular haemoglobin, MCHC- Mean corpuscular haemoglobin concentration, WBC- white blood cells RBC-red blood cells, PCV-packed cell volume
*Range source: Mercks Veterinary Manual, 2012

As shown in Table 7, most of the biochemical constituents recorded were significantly ($p<0.05$) influenced by garlic supplementation except blood cholesterol which was not significantly ($p>0.05$) affected by the inclusion of varying levels of garlic powder. Higher serum total protein and albumin is consistent with Kholif *et al.* (2012) when lactating goats were supplemented with garlic oil. However this result is in contrast to the reports of Adewumi (2008), Rasoul *et al*. (2014) and Anasssori *et al.* (2014) who did not observe any significant difference in serum total protein and albumin when raw garlic and oil were fed to sheep and goat. Decreased serum glucose is consistent with several researchers (Anasssori *et al.,* 2014; Rasoul *et al.,* 2014; Adewumi, 2008). Judson and Leng (1973) observed that increase in glucose level is proportionate to increased ruminal propionate production or absorption. In the present report, propionate production decreased as serum glucose decreased. The result for serum glucose in this present study is in contrast with other reports by several researchers. The decreased serum glucose could be as a result of the concentration of garlic powder used in this study giving that report from Anasssori *et al*. (2014) indicated a decrease from 69.50 mg/dl to 62.75 mg/dl in serum glucose when raw garlic was supplemented in basal diet of sheep at 100 g/kg DM and 75 g/kg DM, respectively. Serum cholesterol only numerically decreased across treatment groups as the amount of garlic powder supplementation increased. The result for serum cholesterol of this present study is similar to that of Anasssori *et al*. (2014) when raw garlic was fed in diet of sheep. Also Adewumi (2008) did not observe a significant difference in serum cholesterol of WAD sheep feed garlic at 1.25 %/100 kg. This present report on serum cholesterol is in contrast with Rasoul *et al.* (2014) who reported a significantly decreased level of serum cholesterol when garlic was fed to sheep and pre-partum Mahabadi goats. The differences found in this study with that of Rasoul *et al.* (2014) could be attributed to the species and or physiological state of the goats used.

Table 7: Effects of varying levels of garlic (*A. sativum*) powder supplementation on serum biochemical constituents of WAD goats

Parameter	*Range	Control	[1]GP0.5	[2]GP1.0	[3]GP1.5	SEM
Total protein (g/dl)	6.1-7.5	10.27[a]	6.00[b]	9.60[a]	9.43[a]	0.63
Albumin (g/dl)	2.3-3.6	6.27[a]	4.00[b]	4.87[ab]	5.23[ab]	0.34
Globulin (g/dl)	2.7-4.4	4.00[ab]	2.33[b]	4.73[a]	4.2[a]	0.35
Glucose (mg/dl)	50-75	55.00[a]	48.33[ab]	42.33[b]	41.67[b]	1.88
Cholesterol (mg/dl)	65-136	76.00	68.00	60.00	53.33	4.91

[abc]Means with different superscript on the same row differ significantly ($p<0.05$)
[1]GP0.5- Garlic (*Allium sativum*) powder at 0.5% level of inclusion
[2]GP1.0- Garlic (*Allium sativum*) powder at 1% level of inclusion
[3]GP1.5- Garlic (*Allium sativum*) powder at 1.5% level of inclusion
*Range source: Mercks Veterinary Manual, 2012

Table 8 shows the cost analysis of feeding different levels of garlic powder to West African Dwarf goats. Cost of total grass consumed was not significant ($p>0.05$) across treatment groups. Total cost of concentrate intake increased significantly ($p<0.05$) as the level of garlic powder inclusion increased. Result of cost per kg weight gain was significantly ($p<0.05$) different across the treatment groups. Significantly higher cost of feed consumed in supplemented group was as a result of market cost of 1 kg garlic powder given that while maize cost ₦63/kg, garlic powder cost ₦3400/kg. It is this same cost of feed consumed that influenced the cost per weight gain which was also significantly higher in supplemented group compared to control.

Table 8. Cost analysis of feeding varying inclusion levels of garlic powder to West African Dwarf goats

Parameters	Control	[1]GP0.5	[2]GP1.0	[3]GP1.5	SEM
Grass intake (kg)	33.71	32.19	31.81	33.48	0.44
Concentrate intake (kg)	12.18	12.21	12.16	12.51	0.22
Total feed consumed (kg)	45.69	44.40	43.97	45.99	0.60
Total cost of grass consumed (₦/kg)	770.92	736.16	727.38	765.53	10.16
Total cost of concentrate consumed (₦/kg)	617.53[d]	822.83[c]	1012.73[b]	1250.70[a]	56.43
Cost of total feed consumed (₦/kg)	1388.45[d]	1559.00[c]	1740.11[b]	2016.22[a]	58.65
Feed cost/kg weight gain (₦/kg)	340.17[c]	385.04[c]	449.06[b]	544.58[a]	19.39

[abcd]Means with different superscript on the same row differ significantly ($p<0.05$)
[1]GP0.5- Garlic (*Allium sativum*) powder at 0.5% level of inclusion
[2]GP1.0- Garlic (*Allium sativum*) powder at 1% level of inclusion
[3]GP1.5- Garlic (*Allium sativum*) powder at 1.5% level of inclusion

Conclusion

Results from this present study indicate that garlic powder did not exert any adverse effect on performance of West African Dwarf goats. Less amount of fermented protein in the rumen will mean more protein will be available in the small intestine for utilization.

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