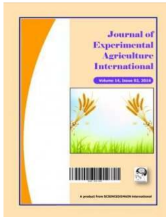

Journal of Experimental Agriculture International

18(5): 1-14, 2017; Article no.JEAI.36602
Previously known as American Journal of Experimental Agriculture
ISSN: 2231-0606

Garlic (*Allium sativum*) Powder as an Additive in Broilers (Finisher Phase) Part 2: Growth Performance, Hypocholesterolemic Effect and Economic Implications

T. A. Oloyede[1] and A. O. Fasuyi[1*]

[1]*Department of Animal Production and Health Sciences, Faculty of Agricultural Sciences, Ekiti State University, Ado-Ekiti, Nigeria.*

Authors' contributions

This work was carried out in collaboration between the two authors. Author TAO was a postgraduate student while author AOF designed the study. The actual field work, laboratory analyses, literature searches and project write-up were jointly done by the two authors. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JEAI/2017/36602
Editor(s):
(1) Rusu Teodor, Professor, Department of Technical and Soil Sciences, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Romania.
(2) Daniele De Wrachien, Professor, State University of Milan, Italy.
Reviewers:
(1) Fernanda Rodrigues Goulart, Federal University of Santa Maria, Brazil.
(2) Filiz Karadaş, University of Yuzuncu Yil, Turkey.
(3) O. Ayoola Mathew, Bowen University, Nigeria.
Complete Peer review History: http://www.sciencedomain.org/review-history/21924

Original Research Article

Received 1st September 2017
Accepted 9th November 2017
Published 15th November 2017

ABSTRACT

This study was designed to investigate the effects of garlic powder as a phyto-additive in broiler diets as a growth promoter with cholesterolemic properties and to also determine the economic implications when garlic powder is used in broiler diets. One hundred and ninety-two day old commercial broilers were used for this experiment and they were randomly allotted to four treatments and four replicates. Powdered garlic was incorporated into the bird's diet at 0 gKg^{-1}, 2 gKg^{-1}, 3 gKg^{-1} and 4 gKg^{-1} additive levels. The performance parameters progressively improved by increasing dietary garlic powder from 2 gKg^{-1} up to 3 gKg^{-1} but reduced when garlic inclusion level was increased beyond 3 gKg^{-1}. The highest average feed intake of 110.13±2.60 g/bird/day was obtained for birds on diet with 2 gKg^{-1} garlic supplementation. The highest average weight gain value of 48.73±2.64 g/bird/day was also obtained for birds on 2gKg^{-1} garlic supplemented diet. The

**Corresponding author: E-mail: ayodeji.fasuyi@eksu.edu.ng;*

optimum feed conversion ratio value of 2.27±0.14 was obtained at 2 gKg^{-1} garlic supplemented diet. The nitrogen retention values were similar (P>0.05) for all experimental birds. The live weight of 2524.70±59.9 g was the highest for birds on 2 gKg^{-1} garlic diet but similar (P>0.05) to the live weight value of 2468.30±26.0 g obtained for birds on 3 gKg^{-1} garlic supplemented diet. The total cholesterol was consistently higher (P<0.05) at 3.41±0.13 g/dl for birds on the control diet without any garlic powder. Other total cholesterol values of 2.43±0.04 g/dl, 2.68±0.16g/dl and 2.69±0.10g/dl obtained for birds on 2 gKg^{-1}, 3 gKg^{-1} and 4 gKg^{-1} garlic supplemented diets, respectively were similar (P>0.05). The highest average body weight was attained on the 56 day for birds on the 2gKg^{-1} garlic supplemented diet and the cost benefit (feed/kg of live weight) was lowest for birds on 2 gKg^{-1} garlic supplemented diet at N243.94 and highest at N290.20 for birds on 4gKg^{-1} garlic supplemented diet. The best performance, carcass characteristics and the serum constituents of birds was attained by the group of birds fed with diet containing 2 gKg^{-1} garlic. The inclusion level of garlic at 2 gKg^{-1} is the most suitable as it is economically cheaper andhad more nutritional benefits for broiler production.

Keywords: Growth performance; carcass characteristics; heamatology; hypocholesterolemic effect.

1. INTRODUCTION

Garlic (*Allium sativum*), a specie in the onion genus, a perennial bulb-forming plant that belongs to the genus *Allium* in the family Liliaceae, has been used for centuries as a flavouring agent, traditional medicine, and a functional food to enhance physical and mental health. One of the main problems encountered in the broiler industry today is that broilers often have excessive deposits of body fat. Abdominal fat is highly correlated with total carcass lipids and is used as the main criterion reflecting excess fat deposits in broilers [1]. Furthermore, fat constitutes the main source of waste in slaughter houses [2]. Excessive abdominal fat reduces both feed efficiency during rearing and lean meat yields after processing.

Poultry with a high abdominal fat content have a low market value. In terms of marketing, economic viability and the recognition of consumers' aversion to excess fatty tissue deposits direct poultry scientists toward the development of new methods to reduce broiler body fat. Fat in a broiler, particularly at the finisher phase of production (at 43 days of age) accounted for as much as 10%-15% of its total carcass weight [3]. According to these figures there is great potential to make feed more efficient and to improve the quality of broiler carcass by further reducing fat deposition. Some nutrition strategies aiming to reduce costs of animal production have the potential to decrease fat accumulation in broiler carcass.

There are ample research evidences indicating that garlic may have had an effect on lipogenesis and triglyceride synthesis in chicken livers [4]. Little research has been done to determine that dietary garlic supplements regulate hepatic lipid metabolism in chickens. The organosulfur content of garlic is primarily that of alliin derivatives, which are reported to been the cause of its low effect on lipids [5].

Although garlic has been used safely in cooking as a popular condiment or flavoring and used traditionally for medicinal purposes in humans, it is commonly known that excessive consumption of garlic can cause problems. Garlic odour on human breath and skin [6] and occasional allergic reactions [7] are recognized. Garlic is not widely used as human food because it gives a repulsive odour and the taste is pungent. However, since monogastric animals are able to incorporate dietary components directly in their tissues [8], supplementary garlic for broilers could mediate in getting the bioactive compounds in garlic, through broiler meat into the human food chain, while avoiding the resentment due to its direct consumption.

However, there is dearth of convincing studies on quantity and form of supplementary garlic in broiler nutrition. This study is therefore aimed at investigating the effects of garlic powder as an additive in broiler diets at finisher phase of growth (26-58 days) using such parameters as growth performance, carcass characteristics, haematology, serum chemistry and the economic implication of broilers chicken fed with garlic supplemented diet at different inclusion levels.

2. MATERIALS AND METHODS

2.1 Location and Procedure

The experiment was conducted at the Poultry Section of the Teaching and Research Farm of Ekiti State University, AdoEkiti, a town in the southwest Nigeria in the rain forest zone on latitude 7° 40 ' North of the equator and longitude 5° 15 ' East of Greenwich Meridian with ambient temperature, 25-37℃; relative humidity,70%; wind, SSW at 11mph (18km/h); barometric pressure, 29.68' Hg(F). Garlic, was purchased from the local market and the garlic powder was prepared by mincing, sun-drying and grinding the dried garlic. Grinding was done using a manual grinding machine until powdery garlic was obtained. The powdered garlic was then incorporated in the finisher diets at $0gKg^{-1}$, 2 gKg^{-1}, $3gKg^{-1}$ and $4gKg^{-1}$ inclusion levels.

2.2 Experimental Diets

Four diets were formulated for this finisher phase. There were 4 experimental rations used as dietary treatments. Diet 1 was the control and contained no garlic powder. Diets 2, 3 and 4 were formulated to contain 2, 3 and $4gKg^{-1}$ of garlic powder, respectively as shown in Table 1.

2.3 Experimental Birds

One hundred and ninety-two day old commercial broilers were randomly allotted to four treatments and four replicates. Each treatment therefore had a total of 48 chicks and each replicate in a treatment had a total of 12 chicks. The chicks were fed on a standard commercial broiler starter diet until the 8^{th} day when the experiment commenced. The birds were fed ad-libitum and clean water was provided throughout the experimental duration. The starter diet was supplied from the 8^{th} to 28th day while the finisher diet was supplied between the 29th and 56^{th} day (end of trial).

2.4 Haematological Parameters

At the end of the feeding trial, birds were randomly selected, weighed and sacrificed by severing the jugular vein and blood allowed to flow freely into labelled bottles one of which contain a speck of ethylene-diamine-tetraacetic acid (EDTA) while the other without EDTA was processed for serum. The blood samples were used for the determination of haematological parameters such as packed cell volume(PCV), red blood cell count (RBC), haemoglobin concentration(Hbc), total white blood cell count (WBC),differential count of white blood cell (leucocyte, neutrophil, monocyte, basophil and eosinophil). The packed cell volume(PCV) was estimated by spinning about 75:1 of each blood sample in heparinized capillary tubes in an haematocrit micro centrifuge for 5 minutes while the total red blood cell (RBC) count was determined using normal saline as the diluting fluid.

Table 1. Broiler starter experimental diets with varying levels of garlic powder

Ingredients	**Broiler starter diets**			
	1	**2**	**3**	**4**
		Garlic inclusion levels		
	Control	**2.0 gKg^{-1}**	**3.0 gKg^{-1}**	**4.0 gKg^{-1}**
Maize (9% CP)	55.00	55.00	55.00	55.00
Soyabean meal(45.0% CP)	37.60	37.60	37.60	37.60
Fish meal(68%CP)	2.00	2.00	2.00	2.00
Palm oil	1.00	1.00	1.00	1.00
Bone meal	2.50	2.50	2.50	2.50
Oyster shell	0.50	0.50	0.50	0.50
Salt	0.50	0.50	0.50	0.50
DL-methionine	0.20	0.20	0.20	0.20
L-lysine	0.20	0.20	0.20	0.20
Premix*	0.50	0.50	0.50	0.50
Total	100.00	100.0	100.00	100.00
Calculated:				
Crude protein (%)	23.30	23.30	23.30	23.30
ME(kcal/kg)	2937.00	2937.00	2937.00	2937.00
Crude fibre(%)	3.96	3.96	3.96	3.96
Ether extract	4.69	4.69	4.69	4.69

**Contained vitamins A (10,000,000iu); D (2,000,000iu); E (35,000iu); K (1,900mg); B12 (19mg);Riboflavin (7,000mg); Pyridoxine (3,800mg); Thiamine (2,200mg); D Panthotenic acid (11,000mg); Nicotinic acid (45,000mg); Folic acid (1,400mg); Biotin (113mg); and trace elements as Cu (8,000mg); Mn (64,000mg); Zn (40,000mg); Fe (32,000mg); Se (160mg); I_2 (800mg); and other items as Co (400mg); Choline (475,000mg);Methionine (50,000mg); BHT (5,000mg) and Spiramycin (5,000mg) per 2.5kg*
*CP: Crude Protein; **ME, metabolizable energy = (0.860+0.629(GE-0.78CF) [16]*

Table 2. Broiler finisher experimental diet with varying levels of garlic powder

Ingredients	Broiler finisher diets			
	1	2	3	4
		Garlic inclusion levels		
	Control	**2.0 gKg^{-1}**	**3.0 gKg^{-1}**	**4.0 gKg^{-1}**
Maize (9% CP)	62.00	62.00	62.00	62.00
Soyabean meal(45.0% CP)	30.60	30.60	30.60	30.60
Fish meal(68% CP)	2.00	2.00	2.00	2.00
Palm oil	1.00	1.00	1.00	1.00
Bone meal	2.50	2.50	2.50	2.50
Oyster shell	0.50	0.50	0.50	0.50
Salt	0.50	0.50	0.50	0.50
DL-methionine	0.20	0.20	0.20	0.20
L-lysine	0.20	0.20	0.20	0.20
Premix*	0.50	0.50	0.50	0.50
Total	100.00	100.00	100.00	100.00
Calculated:				
Crude protein (%)	20.71	20.71	20.71	20.71
ME(kcal/kg)	3007.80	3007.80	3007.80	3007.80
Crude fibre (%)	3.96	3.96	3.96	3.96
Ether extract	4.69	4.69	4.69	4.69

**Contained vitamins A(10,000,000iu); D(2,000,000iu); E(35,000iu);K(1,900mg); B12 (19mg); Riboflavin(7,000mg); Pyridoxine(3,800mg); Thiamine(2,200mg); D Panthotenic acid(11,000mg); Nicotinic acid(45,000mg); Folic acid(1,400mg); Biotin (113mg); and trace elements as Cu(8,000mg); Mn(64,000mg); Zn(40,000mg); Fe(32,000mg); Se(160mg); I_2(800mg); and other items as Co(400mg); Choline(475,000mg); Methionine(50,000mg); BHT(5,000mg) and Spiramycin(5,000mg) per 2.5kg*
CP: Crude Protein, ME: Metabolized Energy [16]

The Haemoglobin concentration (Hbc) was estimated using cyanomethaemoglobin method as described [9], while the mean corpuscular haemoglobin concentration (MCHC), mean corpuscular volume (MCV), low density lipoprotein and globulin were calculated. Biochemical parameters such as total serum protein, albumin, cholesterol (total cholesterol, triglycerides, high density lipoprotein, low density lipoprotein) were estimated. Total serum protein was determined colorimetrically using the SIGMA assay kits. The albumin and the globulin were determined using the described method [10].

2.5 Estimation of Total Cholesterol, High Density Lipoprotein Cholesterol (HDLP) and Low Density Lipoprotein Cholesterol (LDLP)

Total cholesterol in all the samples collected as measured by cholesterol CHOD-PAP method which is an enzymatic end point method [11]. High density lipoprotein (HDLP) in the samples were separated by precipitation through the procedure adopted [12].

Low density lipoprotein cholesterol (LDLC) in the samples were determined using the relationship described [13].

2.6 Carcass and Organ Characteristics

Two birds from each replicate were slaughtered on the last day of each phase of the experiment. The carcasses were scalded before defeathering and the dressed chicks were later eviscerated. The measurements of the carcass traits: dressed weights, eviscerated weight, thigh, drumsticks, shank, back, necks, wing, belly-fat and head were taken before dissecting out the organs. The organs measured were the liver, lungs, spleen, heart and gizzard. All the carcass traits except the dressed and eviscerated weights were expressed as percentages of the live weight while the organs were expressed in g/kg body weight.

2.7 Determination of Nitrogen Retention and Apparent Nitrogen Digestibility

Total feaces voided during the last five days were collected, weighed, and then sun dried to a constant weight and then preserved while the corresponding feed consumed was also recorded for nitrogen studies. The nitrogen contents of the samples were determined [14]. Nitrogen retained was calculated as the algebraic difference between feed nitrogen and faecal nitrogen (on dry matter basis) for the period. Apparent nitrogen digestibility was computed by expressing the nitrogen retained as a fraction of the nitrogen intake multiplied by 100.

2.8 Economics of Production/Cost Analysis

The market cost of the ingredients at the time of the study, feed intake, body weight gain, total revenue/bird and total net returns/birds were used to calculate the total cost of feed per 100kg of the diet, cost of feed per kg diet and total cost of feed consumed per bird. Feeding cost values were expressed in terms of Nigerian Naira (N) currency.

2.9 Statistical Analysis

Data were subjected to analysis of variance (ANOVA) using Minitab Analytical Computer Package (Minitab Ver. 16) [15] to separate and compare significant differences among the mean values where necessary at a level of $P<0.05$.

3. RESULTS AND DISCUSSION

3.1 Performance Characteristics at Finisher Phase (28-56 Days)

The performance characteristics of broiler chicken at 28-56days are on Table 3. The highest average feed intake (AFI) of 110.13±2.60g/bird/day was obtained for birds on diet 2 with $2gKg^{-1}$ garlic supplementation. However, this value was similar ($P>0.05$) to 108.50±2.13g/bird/day obtained for birds on diet 3 of $3gKg^{-1}$ garlic supplementation. The lowest feed intake of 104.72±0.73g/bird/day obtained for birds on diet 4 of $4gKg^{-1}$ garlic supplementation was also similar ($P>0.05$) to 105.8±1.53g/bird/day obtained for the birds on the control diet without dietary garlic.

The average weight gain (AWG) value of 48.73±2.64g/bird/day obtained for birds on 2 gKg^{-1} garlic supplemented diet was the highest but also similar ($P>0.05$) to the values obtained for birds on $3gKg^{-1}$ garlic supplemented diet. The lowest AWG of 40.59g/bird/day was obtained for birds on $4gKg^{-1}$ garlic supplemented diet albeit similar ($P>0.05$) to the value of 42.32±1.47g/bird/day obtained for birds on the control diet without garlic supplementation.

The feed conversion ratio (FCR) of 2.27±0.14 was the lowest and optimum for birds on $2gKg^{-1}$ garlic supplemented diet, while the highest value of 2.60 ± 0.28 was obtained for birds on $4gKg^{-1}$ garlic supplemented diet. However, all FCRs values were not significantly different ($P>0.05$).

Similar protein efficiency ratio (PER) results was obtained for birds on all diets without significant differences ($P>0.05$) for all PER values. However, the highest value of 2.14±0.12 was obtained for birds on $2gKg^{-1}$ garlic supplemented diet and the lowest value of 1.87±0.19 obtained for birds on $4gKg^{-1}$ garlic supplemented diet.

The highest feed intake values consistently obtained for birds on $2gKg^{-1}$ garlic supplemented diets in this finisher phase-corroborated earlier study on garlic supplementation in broilers. Previous studies all reported improved feed intake up to $3gKg^{-1}$ garlic supplementation and subsequent reduction in feed intake thereafter [17,18,19]. The lowest feed intake values in the present study were obtained for birds on $4gKg^{-1}$ garlic supplemented diet in the finisher phases which was still in agreement with previous researchers [17,18,19]. It was also reported that feed consumption was significantly higher in broilers fed diets with lower concentration of garlic at 0.125-0.25% compared with higher levels of 0.5, 1.0 and 2.0% [20]. It was summarized that feed intake reduction with garlic supplementation was probably due to the associated flavour factor and the need of chickens to get adapted to the supplement during the first few weeks of feeding [21].

The average weight gain values of birds on $2gKg^{-1}$ garlic supplemented diets were significantly higher than other levels of garlic supplementation except for birds on $3gKg^{-1}$ garlic supplemented diets in both starter and finisher phases. These results were in agreement with several previous similar studies [22, 23]. They opined that broiler body weights were improved when they were fed garlic at 1g/kg in the basal diet.

The optimum feed conversion ratio value obtained for birds on 2 gKg^{-1} at the starter phase of broiler production agreed with previous studies [23,24]. It has been reported that administration of 100mg of garlic resulted in improved body weight gain at 7, 14 and 21 days of treatment in broiler chicks although there was no change in FCR [22].

Although the present research study had a positive affinity for birds on $2gKg^{-1}$ garlic supplemented diet as having the best values for feed intake, weight gain and feed conversion ratio, some previous studies considered these parameters as controversial [25,26] and could not trace any effect of garlic supplementation on the performance of broiler chicks. The wide range of results instead of the established beneficial role of garlic as growth promoter has been attributed to the dose, duration and processing of the medicinal plants as well as the experimental conditions [27]. It was earlier suggested that differences in the results determined by different authors may be due to the use of different commercial products of garlic [28]. The commercial garlic products may be divided into raw garlic (allicin rich) and processed garlic (non-allicin rich) which differs in the active substances contained [27].

Even though the protein efficiency ratio (PER) values of birds on 2gKg^{-1} garlic supplemented diets (starter and finisher phases) were higher but similar statistically with other values, evidence abound that garlic had beneficial effects on feed efficiency and growth of broiler chickens [25]. These beneficial effects were suggested to be the enhancement of the activity of pancreatic enzymes and the provision of conducive environment for better absorption of nutrients [29].

3.2 Nitrogen Utilization

Nitrogen utilization is shown in Table 4. Nitrogen intake value at 2.6±0.32gN/chick/day was the highest for birds on the control diet without garlic but similar (P>0.05) to the average values of 2.4±0.22gN/ chick/ day obtained for birds on 2gKg^{-1} and 3gKg^{-1} garlic supplemented diets. The Nitrogen retention were similar (P>0.05) for all experimental birds with an upper range of 2.0±0.25gN/ chick/ day for birds on the control diet without garlic powder and a minimum range of 1.60±0.27gN/ chick/ day for birds on the 4gKg^{-1} garlic supplemented diet.

The apparent nitrogen digestibility (AND) had similar values (P>0.05) for all experimental birds with an upper range of 80.00±3.31% for birds on the 4gKg^{-1} garlic supplemented diet and a lower range of 77.70±0.76% for birds on both 2gKg^{-1} and 3gKg^{-1} garlic supplemented diets.

The daily nitrogen intake (NI) values showed some variations among the treatment diets. Birds on the control diet without garlic powder had the highest value, though similar to other birds on 2gKg^{-1} and 3gKg^{-1}garlic supplemented diets, but significantly different to birds on 4 gKg^{-1} garlic supplemented diet. This result implies that garlic inclusion as a supplement in broiler diets has no effect on the nitrogen intake up to 3 gKg^{-1} garlic powder. The nitrogen intake can therefore be said to be sufficient at levels not exceeding 3 gKg^{-1} inclusion of garlic powder.

The Nitrogen retention of the birds on experimental diets was also similar. The retention of nitrogen correlated positively with nitrogen intake which implies that the higher the nitrogen intake, the higher the nitrogen retained subject to requirement levels since any nitrogen consumed in excess of requirement would be degraded and voided in faeces [30]. The apparent nitrogen digestibility were not significantly (P>0.05) affected.

3.3 Carcass Characteristics of Broilers (28-56 Days)

The carcass characteristics Table is presented in Table 5. The live weight of 2524.70±59.9g was the highest for birds on 2gKg^{-1} garlic diet but similar (P>0.05) to the live weight value of 2468.30±26.0g obtained for birds on 3gKg^{-1} garlic supplemented diet. The dressed weight percentage of 242.25±14.2% was also the highest value but similar (P>0.05) to dressed weight value of 232.93±27.2% obtained for birds on 3gKg^{-1} garlic supplemented diet. Ditto for eviscerated weight of 215.00±25.5% obtained for birds on 2gKg^{-1} garlic diet which was the highest value but similar (P>0.05) to 200.95±24.0% obtained for birds on 3gKg^{-1} garlic supplemented diet. The eviscerated weight of 184.40±33.9% obtained for birds on 4gKg^{-1} garlic diet was the lowest value but similar (P>0.05) to 185.50±34.5% obtained for birds on the control diet without garlic.

The mean values for thighs, drumsticks, backs, shanks, wings, heads and neck were consistently higher for birds on 2gKg^{-1} garlic supplemented diet. The thigh value of 293.00±4.25g/kg body weight was the highest for birds on 2gKg^{-1} garlic diet but similar (P>0.05) to 276.25±3.89g/kg body weight obtained for birds on diet 3 of 3gKg^{-1} garlic. The lowest thigh value of 243.75±8.13g/kg body weight was obtained for birds on 4gKg^{-1} garlic diet.

The mean weight of drumsticks obtained for birds on 2gKg^{-1} garlic diet at 150.00±12.73g/kg body weight was the highest value although similar (P>0.05) to 145.50±8.49g/kg body weight obtained for birds on 3gKg^{-1} garlic diet. Drumstick weight of 106.25±1.06g/kg body weight obtained for birds on 4gKg^{-1} garlic diet was the lowest but similar (P>0.05) to 107.25±3.18g/kg body weight obtained for birds on the control diet without garlic. The back weight and shank weight of birds on 2gKg^{-1} garlic diet were also the highest at 281.50±19.09 and 52.25±8.84g/kg body weight, respectively. However, these values were similar (P>0.05) to all back weight and shank values of all experimental birds.

The mean wing weight of 136.25±3.89g/kg body weight was the highest for birds on 2gKg^{-1} garlic diet but similar (P>0.05) to 133.00±3.54g/kg body weight obtained for birds on 3gKg^{-1} garlic diet. Mean wing weight value of 100.50±2.12g/kg body weight obtained for birds on 4gKg^{-1} garlic diet was the lowest but similar (P>0.05) to 104.75±4.60g/kg body weight obtained for birds on the control diet without garlic. Likewise the mean values for the dissected heads and necks of birds on 2gKg^{-1} garlic diets were consistently higher numerically than other values although statistically similar (P>0.05).The back fat value of 1.20±0.28g/kg body weight obtained for birds on 2gKg^{-1} garlic diet was the lowest albeit similar (P>0.05) to the other back fat values obtained for experimental birds.

The highest live weight, dressed weight and eviscerated weight values for birds on 2gKg^{-1} garlic supplemented diets at this finisher phase could only suggest a better growth rate of birds on 2 gKg^{-1} garlic supplemented diets. Birds on 2 gKg^{-1} garlic supplemented diet had higher values which in most cases were significantly higher than other values for thighs, drumsticks, wings, necks, heads, backs and shanks of other birds on other garlic supplemented diets of 3 gKg^{-1} and 4 gKg^{-1}.

The lowest values for these carcass cuts were consistently obtained for birds on 4gKg^{-1} garlic supplemented diets in both starter and finisher phases of the broiler experiment. The findings of the current study agreed with a previous work [31] who found that feed intake and FCR, body weight and carcass quality (dressing percentage, breast weight and leg weight) were improved in a 35 day experimental trial, when broilers were supplemented (at the rate of 10ml/liter of drinking water) with an aqueous extract of medicinal plants containing garlic. It was also demonstrated that garlic powder had a significant effect on carcass yield when added into broiler feed [32]. However, several previous studies on garlic supplementation in broiler diets suggested that garlic supplementation failed to produce positive effects on carcass yield in term of dressing percentage [33] and carcass characteristics in term of percentage of carcass, small intestines, proventriculus, gizzard, liver and abdominal fat [34].

3.4 Relative Organ Weight at 28-56 Days

Except for lungs that were significantly higher (P>0.05) at 18.50±0.71g/kg body weight for birds on 2gKg^{-1} garlic supplemented diet, all other organs investigated such as liver, heart, spleen and gizzard had statistically similar (P>0.05) values. However, higher numerical values for all organs investigated were obtained for birds on 2gKg^{-1} garlic supplemented diets. These results were corroborated by some previous studies [22,25,33,34,35].

3.5 Haematological Indices of Birds on Garlic Supplemented Diets (28-56 Days)

Apart from haemoglobin concentration (Hbc), lymphocytes, neutrophil and mean cell haemoglobin concentration (MCHC), all other investigated blood parameters such as packed cell volume (PCV), red blood cell (RBC), total white blood cells(TWBC), monocytes, eosinophil, basophil, mean cell haemoglobin (MCH) and mean cell volume (MCV) had similar values (P>0.05) for all experimental birds on the experimental diets.

The PCV had the highest value of 35.00±12.73% for birds on 2gKg^{-1} although similar (P>0.05) even to the lowest PCV value of 29.00±2.83% obtained for birds on the control diet without garlic supplementation.

The Hbc value of 13.72±0.09g/100ml obtained for the birds on the control diet without garlic was significantly higher (P<0.05) than other values. The Hbc values of 8.97±1.78 g/100 ml, 8.15±1.78 g/100 ml and 8.44±1.44 g/100 ml were similar (P>0.05). The RBC values obtained for all birds on all experimental diets were similar (P>0.05) with the highest value of 2.86±0.23 × 10^6/ mm obtained for birds on the 2gKg^{-1} garlic supplemented diet.

The TWBC values were similar (P>0.05) for all experimental birds on all diets with a range of 5.50±2.12 × 10^9/ L for birds on the control diet without garlic and 5.00±0.12 × 10^9/ L for birds on the 2gKg^{-1} garlic diet. The neutrophil value of 46.00±0.36% was the highest but similar (P>0.05) to 39.00±7.07% and 30.00±2.83% obtained for birds on the control diet without garlic and the 3gKg^{-1} garlic supplemented diet, respectively. The lymphocytes were highest at 54.00±0.70% for the birds on the control diet without garlic but similar (P>0.05) to 42.00±2.83% and 52.00±2.83% obtained for birds on the 3gKg^{-1} and 4gKg^{-1} garlic supplemented diets, respectively.

The monocytes values were similar (P>0.05) for all birds on the experimental diets with a highest range of 11.00±1.41% for birds on the 4gKg^{-1} garlic supplemented diet and a lowest range of 8.00±2.83% for birds on the control diet without garlic. The eosinophil values were similar (P>0.05) for all experimental birds on all diets with a highest range of 10.00±5.66% for bird s on the control diet without garlic and a lowest range of 6.50±0.71% for birds on 2gKg^{-1} garlic supplemented diet.

The basophil values were similar (P>0.05) as birds on the 2gKg^{-1}, 3gKg^{-1} and 4gKg^{-1} had the same value of 2.00%. Birds on the control diet without garlic supplementation had the least but similar (P>0.05) value of 1.00±1.41%. The MCH values were also similar (P>0.05) with an upper range of 4.81±0.35pg for birds on the control diet without garlic and a lower range of 3.35±0.05pg for birds on 3gKg^{-1} garlic supplemented diet.

The MCHC value of 4.75±0.43% obtained for birds on the control diet without garlic was the highest but similar (P>0.05) to 2.70±0.79% and 2.85±0.28% obtained for birds on 2gKg^{-1} and 4gKg^{-1} garlic supplemented diets, respectively. The MCV values were all similar (P>0.05) for all birds on the experimental diets with a highest range of 136.43±10.12 µm^3 for birds on 2gKg^{-1} garlic supplemented diet and a lowest range of 101.32±1.87 µm^3 for birds on the control diet.

Except for some inconsistencies in haematological parameters investigated at both starter and finisher phases of the broiler experiment, most blood parameters had similar values. Since blood has been singularly identified as having immune-modulatory effects which can be used in the assessment of the health status of the animal, it can be adjudged from the present result that the non-lymphoid parts of the immune system such as blood monocytes and tissue macrophages may not have actively played any significant role in the immune system of the experimental birds. This assumption could be exemplified as most blood parameters on the garlic supplemented diets had similar values with the control garlic free diets.

However, the survivability of the experimental birds may indicate a possible immune potentiating effect of garlic in the diets containing garlic powder as supported by previous studies [36,37,38,39].

3.6 Serum Metabolites of Chickens (28-56 Days)

The total cholesterol was consistently higher (P>0.05) at 3.41±0.13g/dl for birds on the control diet without any garlic powder. Other total cholesterol values of 2.43±0.04g/dl, 2.68±0.16g/dl and 2.69±0.10g/dl obtained for birds on 2gKg^{-1}, 3gKg^{-1} and 4gKg^{-1} garlic supplemented diets, respectively were similar (P>0.05).

The high density lipoprotein (HDL) had the highest value of 2.56±0.16g/dl for birds on the control diet without garlic powder. Other HDL values of 1.35±0.14g/dl, 1.35±0.07g/dl and 1.58 0.03g/dl obtained for birds on 2gKg^{-1}, 3gKg^{-1} and 4gKg^{-1} garlic supplemented diets, respectively were similar (P>0.05). The low density lipoprotein (LDL) also had the highest value of 1.83±0.06g/dl for birds on the control diet without garlic powder. The other LDL values of 0.48±0.11g/dl, 0.59±0.01g/dl and 0.72±0.09g/dl were similar (P>0.05) for birds on 2gKg^{-1}, 3gKg^{-1} and 4gKg^{-1} garlic supplemented diets, respectively.

The triglyceride level was also significantly highest (P<0.05) at 1.34±0.16g/dl for birds on the control diet without garlic powder. Other triglyceride levels of 0.30±0.12g/dl, 0.31±0.11g/dl and 0.33±0.11g/dl obtained for birds on 2gKg^{-1}, 3gKg^{-1} and 4gKg^{-1} garlic supplemented diets were similar (P>0.05).

The total serum protein (TSP) had the highest value of 8.30±0.20g/dl for birds on 2gKg^{-1} garlic supplemented diet. This value was however similar (P>0.05) to 8.27±0.18g/dl and 8.25±0.08g/dl obtained for birds on 3gKg^{-1} and 4gKg^{-1} garlic supplemented diets, respectively. The lowest significant (P<0.05) TSP value of 7.38±0.32g/dl was obtained for birds on the control diet without garlic powder.

The albumin level had a lowest range of 3.60±0.91g/dl for birds on the control diet without garlic powder and the highest range of 4.17±0.03g/dl for birds on $2gKg^{-1}$ garlic supplemented diet. However, there were similarities (P>0.05) between the highest albumin value of 3.60±0.91g/dl for birds on the control garlic free diet and 3.93±0.08g/dl for birds on the $4gKg^{-1}$ garlic supplemented diet. The globulin levels were similar (P>0.05) for all experimental birds on the garlic free diet, $2gKg^{-1}$, $3gKg^{-1}$ and $4gKg^{-1}$ garlic supplemented diets at 3.78±0.51g/dl, 4.13±0.20g/dl, 4.20±0.20g/dl and 4.32±0.09g/dl, respectively.

The total cholesterol (TC) contents were significantly reduced in serum metabolites of all birds on the garlic supplemented diets at starter and finisher phases of this broiler experiment. The anti-cholesterolemic effects of garlic are well documented. It has been that varying supplementary levels of garlic in poultry birds has decreased egg yolk cholesterol of laying hens [40,41], reduced plasma cholesterol in broilers fed garlic at 10,000mg/kg in 35 days treatment [25] and reduced serum cholesterol concentration in white Leghorn pullets [42].

There was also significant decrease in the serum contents of high density lipoprotein (HDL), low density lipoprotein (LDL). The triglyceride contents of sera were also lower for birds on the garlic supplemented diets [23,42,43]. A reduction of 28-41% in low density lipoprotein (LDL) cholesterol in an experimental diet containing 3.8% garlic paste had been reported [42]. Reductions in total cholesterol, LDL-cholesterol and triglycerides had been reported when broilers were supplemented with 1g/kg garlic [23]. It was also reported that garlic powder decreased total cholesterol, triglycerides and low density lipoprotein [43].

The significant reduction in LDL in all garlic supplemented diets compared to the levels in birds of the control group in this present study can be connected to the possible mechanism of anti-oxidant and anti-peroxide lowering action of garlic powder (S-allyl cysteine sulfoxide) on LDL or the decrease in hepatic production of very low density lipoprotein (VLDL) also referred to “very bad” cholesterol. The VLDL serves as the precursor of LDL in the blood circulation. The significant decreases in total cholesterol, triglycerides and LDL in garlic supplemented diets in the present study were similar to previous findings [44]. This may be due to the possible mechanism of hypocholesterolemic and lipolipidemic action of garlic powder which depresses the hepatic activities of lipogenic and cholesterogenic enzymes such as malic enzyme, fatty acid synthase, glucose-6-phosphatase dehydrogenase [42,45] and 3-hydroxyl-3-methyl-glutaryl-CoA (HMG-CoA) reductase [46]. It has also been reported that polyunsaturated fatty acids prevent atherosclerosis through the formation of cholesterol esters (Afzal et al., 1985). Further findings reported the possibility of garlic powder facilitating activity of enzymes which are involved in the conversion of cholesterol to bilious acids and subsequently reduce the cholesterol content in the carcass [47].

The total serum protein (TSP), albumin and globulin levels were mostly similar among all dietary treatments in this study except for the noticeable but not significant higher values obtained for birds on the garlic supplemented diets. Significant differences were not expected among the serum parameters (TSP, albumin and globulin) examined in this current study since all diets were ensured to be iso-nitrogenous. However, the suggested hypolipidic and hypocholesterolemic potentials of garlic powder may have engendered some positive metabolic effects on the nitrogen utilization by birds on the garlic supplemented diets.

3.7 Economics of Production/Cost Analysis

The highest average body weight was 2517.30g/bird for birds on the $2gKg^{-1}$ garlic supplemented diet followed by 2475.50g/bird, 2341.10g/bird and 2289.70g/bird for birds on $3gKg^{-1}$ garlic supplemented diet, control diet without garlic and $4gKg^{-1}$ garlic supplemented diet, respectively in that order. The total average feed intake was also highest at 2.64kg for birds on $2gKg^{-1}$ garlic supplemented diet and lowest at 2.51kg for birds on $4gKg^{-1}$ garlic supplemented diet.

The unit cost of feed expectedly, was highest for diet 4 with the highest supplementary level of $4gKg^{-1}$ of garlic powder and lowest for the control diet without any garlic powder. However, the total cost of feed consumed (total feed intake × cost of feed consumed) had N286.44 as the highest cost for birds on $3gKg^{-1}$ garlic supplemented diet followed by N285.45 being the total cost of feed consumed by birds on $2gKg^{-1}$ garlic supplemented diet. The birds on the control diet without garlic powder had the lowest total cost of feed consumed at N259.00.

The cost of feed/kg live weight was lowest for birds on 2gKg^{-1} garlic supplemented diet at N243.94 and highest at N290.20 for birds on 4gKg^{-1} garlic supplemented diet. The highest average body weight was attained at the termination of the experiment on the 56 day for birds on the 2gKg^{-1} garlic supplemented diet. Even though the highest feed intake was also recorded for birds on the 2gKg^{-1} garlic supplemented diet, the cost of feed per kg live weight was lowest for the same set of birds on the 2gKg^{-1} garlic supplemented diet.

Table 3. Production performance of broiler chicken fed garlic powder from 28-56 days of age (finisher phase)

	Treatments			
	1	**2**	**3**	**4**
Supplementary Garlic (gKg^{-1})				
Parameters	**0 (Control)**	**2.0**	**3.0**	**4.0**
AFI (g/bird/day)	105.8±1.53^{b}	110.13±2.60^{a}	108.50±2.13^{ab}	104.72±0.73^{b}
AWG (g/bird/day	42.32±1.47^{ac}	48.73±2.64^{b}	47.38±1.29^{ab}	40.59±4.19^{c}
FCR	2.50±0.06	2.27±0.14	2.29±0.11	2.60±0.28
PER	1.93±0.05	2.14±0.12	2.11±0.10	1.87±0.19
Mortality (%)	0.00	0.00	0.00	0.00

Mean ± Standard deviation; (a, b, c) Means in the same row with the different superscript are significantly different at (P>0.05). AFI, average Feed Intake; AWG, average Weight Gain; FCR, Feed Conversion Ratio; PER, Protein Efficiency Ratio

Table 4. Nitrogen utilization of broilers fed garlic powder from 28-56 days of age (finisher phase)

	Treatments			
	1	**2**	**3**	**4**
Supplementary Garlic (gKg^{-1})				
Parameters	**0 (Control)**	**2.0**	**3.0**	**4.0**
NI (gN/chick/day)	2.6±0.32^{a}	2.4±0.22^{ab}	2.4±0.22^{ab}	2.0±0.25^{b}
NR (gN/chick/day)	2.03±0.25	1.86±0.21	1.86±0.21	1.60±0.27
AND (%)	78.08±1.45	77.50±0.76	77.50±0.76	80.00±3.31

Mean ± Standard deviation; (a, b) Means in the same row with the different superscripts are significantly different at (P>0.05).

NI,Nitrogen Intake; NR, Nitrogen Retention; AND, Apparent Nitrogen Digestibility

Table 5. Carcass trait of broiler chicken fed garlic powder from 28-56 days of age (finisher phase)

	Treatments			
	1	**2**	**3**	**4**
Supplementary Garlic(gKg^{-1})				
Parameters	**0 (Control)**	**2.0**	**3.0**	**4.0**
Live Weight (g)	2263.90± 42.2^{a}	2524.70±49.90^{b}	2468.30± 26.00^{b}	2262.40±34.6^{a}
Dressed Weight (%)	211.90±12.70^{a}	242.25±14.20^{b}	232.93±27.20^{ab}	206.86±23.30^{a}
Eviscerated Weight (%)	185.50±34.50^{a}	215.00± 25.50^{b}	200.95±24.00^{ab}	184.40±33.9^{a}
Thigh (g/kg body wt)	252.50±10.61^{ac}	293.00±4.25^{b}	276.25±3.89^{ab}	243.75±8.13^{c}
Drumstick (g/kg body 8wt)	107.25± 3.18^{a}	150.00±12.73^{b}	145.50±8.49^{b}	106.25±1.06^{a}
Back (g/kg body wt)	249.00± 33.94	281.50±19.09	262.50±24.75	233.50±10.61
Shank (g/kg body wt)	44.50± 9.19	52.25±8.84	45.50±13.44	37.75±2.48
Wing (g/kg body wt)	104.75±4.60^{a}	136.25±3.89^{b}	133.00±3.54^{b}	100.50±2.12^{a}
Head (g/kg body wt)	66.50± 5.00	76.00±7.07	70.50±12.02	62.00±7.07
Neck (g/kg body wt)	108.50± 6.36	134.00±7.07	130.50±19.09	113.00±31.11
Back Fat (g/kg body wt))	2.15±0.21	1.20±0.28	1.25±0.35	1.45±0.35

Mean ± Standard deviation; (a, b, c) Means in the same row with the different superscript are significantly different at (P>0.05)

Table 6. Relative organ traits (g/kg body weight) of broiler chicken fed garlic powder from 28-56 days of age (finisher phase)

	Treatments			
	1	**2**	**3**	**4**
Supplementary Garlic (gKg^{-1})				
Parameters	**0 (Control)**	**2.0**	**3.0**	**4.0**
Liver	48.00± 1.41	50.50±12.02	48.00±8.49	47.00±1.41
Heart	11.50± 2.12	15.50±0.71	14.00±1.41	10.00±1.41
Spleen	3.50 ± 0.71	4.50±0.71	4.00±0.74	3.00±1.41
Gizzard	39.50±3.54	50.00±1.41	48.00±4.24	38.50±9.19
Lungs	14.00 ± 0.91^{ab}	18.50 ± 0.71^{b}	16.00 ± 1.41^{ab}	11.50 ± 2.12^{a}

Mean ± Standard deviation; (a, b) Means in the same row with the different superscript are significantly different at (P>0.05)

Table 7. Haematology of broiler chicken fed garlic powder from 28-56 days of age (finisher phase)

	Treatments			
	1	**2**	**3**	**4**
Supplementary Garlic (gkg^{-1})				
Parameters	**0 (Control)**	**2.0**	**3.0**	**4.0**
PCV (%)	29.00 ± 2.83	35.00± 12.73	31.50± 2.12	29.50± 2.12
Hbc (g/100ml)	13.72 ± 0.09^{a}	8.97 ± 0.69^{b}	8.15 ± 1.78^{b}	8.44 ± 1.44^{b}
RBC (X $10^3/mm^3$)	2.86 ± 0.23	2.28 ± 0.74	2.43 ± 0.50	2.51 ± 1.03
TWBC (x10^9/L)	5.50 ± 2.12	5.00± 0.12	5.25 ± 0.07	5.30 ± 0.14
Neutrophil (%)	39.00 ± 7.07^{ab}	46.00 ± 0.36^{b}	30.00 ± 2.83^{ab}	26.00 ± 2.83^{a}
Lymphocytes (%)	54.00 ± 0.70^{a}	36.00 ± 5.66^{b}	42.00 ± 2.83^{ab}	52.00 ± 2.83^{a}
Monocytes (%)	8.00 ± 2.83	10.00± 2.83	10.00± 2.83	11.00± 1.41
Eosinophil (%)	10.00±5.66	6.50± 0.71	7.00± 1.41	8.00± 2.83
Basophil (%)	1.00 ± 1.41	2.00 ± 0.12	2.00 ± 0.20	2.00± 0.34
MCH (pg)	4.81±0.35	4.20±1.66	3.35±0.05	3.54±0.89
MCHC (%)	4.75 ± 0.43^{a}	2.70 ± 0.79^{ab}	2.57 ± 0.39^{b}	2.85 ± 0.28^{ab}
MCV (μm^3)	101.32±1.87	136.43± 10.12	131.47±18.05	126.49±43. 58

Mean ± Standard deviation; (a, b, c) Means in the same row with the different superscript are significantly different at (P>0.05). PCV = Packed Cell Volume, Hbc = Haemoglobin Concentration, RBC = Red Blood Cell, TWBC = Total White Blood Cell, MCH = Mean Cell Haemoglobin, MCHC = Mean Cell Haemoglobin Concentration, MCV = Mean Cell Volume

Table 8. Serum analyses of broiler chicken fed garlic powder from 28-56 days of age (finisher phase)

	Treatments			
	1	**2**	**3**	**4**
Supplementary Garlic (gKg^{-1})				
Parameters	**0 (Control)**	**2.0**	**3.0**	**4.0**
Total Cholesterol (mmol/l)	3.41 ± 0.13^{a}	2.43 ± 0.04^{b}	2.68 ± 0.16^{b}	2.69 ± 0.10^{b}
HDL(mmol/l)	2.56 ± 0.16^{a}	1.35 ± 0.14^{b}	1.35 ± 0.07^{b}	1.58 ± 0.32^{b}
LDL (mmol/l)	1.83 ± 0.06^{a}	0.48 ± 0.11^{b}	0.59 ± 0.01^{b}	0.72 ± 0.09^{b}
Triglycerides (mmol/l)	1.34 ± 0.16^{a}	0.30 ± 0.12^{b}	0.31 ± 0.11^{b}	0.33 ± 0.11^{b}
Total Serum Protein (g/dl)	7.38 ± 0.32^{a}	8.30 ± 0.20^{b}	8.27 ± 0.18^{b}	8.25 ± 0.08^{b}
Albumin (g/dl)	3.60 ± 0.09^{a}	4.17 ± 0.03^{b}	4.07 ± 0.02^{b}	3.93 ± 0.08^{ab}
Globulin (g/dl)	3.78±0.51	4.13±0.20	4.20±0.20	4.32± 0.09
Albumin / Globulin	0.95±1.78	1.01±0.15	0.97±0.10	0.91±0.89

Mean ± Standard deviation; (a, b) Means in the same row with the different superscript are significantly different at (P>0.05).
HDL, High Density Lipoprotein; LDL, Low Density Lipoprotein

Table 9. Economic production of broiler chickens fed supplementary garlic powder at the finisher phase

	Treatments			
	1	**2**	**3**	**4**
Supplementary Garlic (gKg^{-1})				
Parameters	**0**	**2.0**	**3.0**	**4.0**
Initial Body Weight (g/bird)	1325.40	1347.80	1338.50	1315.50
Final Body Weight (g/bird)	2341.10	2517.30	2475.50	2289.70
Total Weight Gain (g/bird)	1015.70	1169.50	1137.00	974.20
Total feed intake (kg/bird)	2.54	2.64	2.60	2.51
Unit cost of feed consumed (N/kg)	102	108	110	112
Total Cost of Feed Consumed (N/kg)	259.00	285.45	286.44	281.49
Total Weight Gain (kg/bird)	1.02	1.17	1.14	0.97
Cost of Feed/kg live weight gain (N/kg)	253.92	243.97	251.26	290.20

N, Nigeria Naira currency

The economic implication suggests that the most profitable or highest total net returns per bird was obtained for broiler birds fed 2gKg^{-1} garlic supplemented diets. It is surmisable that in spite of the additional cost of garlic supplementation, birds on 2gKg^{-1} garlic supplemented diet were economically raised and would bring better net returns in the event of a commercial production of broiler birds on the present experimental supplemental range of garlic powder.

4. CONCLUSION

Empirical evidence exists to the conclusion that broiler birds that were fed 2gKg^{-1} garlic supplemented diets had the best growth performance, carcass characteristics (the highest live weight, dressed weight and eviscerated weight) and the least cholesterol deposition (serum parameter), though; the haematological parameters were not significantly affected by garlic supplementation in broiler diets. Survivability of the broiler could be enhanced by supplementation in broiler diets. Birds on 2gKg^{-1} garlic supplemented diets had the best net returns per bird and ultimately the most profitable ration in the present study. There is ample evidence that overdosing of garlic powder in broiler diet particularly at supplemented inclusion of 4gKg^{-1} had a diminishing return effect such that the birds on such diets had the poorest growth performance, sub-optimal blood evaluation indices and non-economic production indices.

ETHICAL APPROVAL

As per international standard or university standard ethical approval has been collected and preserved by the author(s).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Chambers JR. Genetics of growth and meat production in chickens. Quantitative Genetics and Selection. 1990;599–643.
2. Zerehdaran S, Vereijen ALJ, Van Arendonk JAM, Van Der Waaij EH. Estimation of genetic parameters for fat deposition and carcass traits in broilers. Poult Sci. 2004;83:521–525.
3. HavensteinGB, Ferket PR,Qureshi MA. Carcass composition and yield of 1957 versus 2001 broilers when fed representative 1957 and 2001 broiler diets. Poult. Sci. 2003;82:1509–1518.
4. Ala Al Deen Jawad H. Some haematological and biochemical effects of garlic on broiler chickens. Bas. J. Vet. Res. 2007;6(2):56-63.
5. Shahriari A, Fatemi Tabatabaie A, Jafari RA, Ghorbanzadeh B. Modulation of serum and liver triglyceride and abdominal fat pad weight by dietary garlic in male broilers. Int. J. Vet. Res. 2009;3(2):101-105.
6. Mader FH. Treatment of hyperlipidemia with garlic-powder tablets. Evidence from the German Association of General Practitioners' multicentric placebo-controlled double-blind study. Arzneim Forsch. 1990;40(10):1111-1116.
7. Siegers CP. *Allium sativum.* De Smet, P.A.G.M. Keller, K Hänsel, R. Chandler, R. F. eds. Adverse Effects of Herbal Drugs. 1992*;73*-77 Springer-Verlag Berlin, Germany.

8. Onibi GE, Scaife JR, Murray I, Fowler VR. Supplementary _- tocopherol acetate in full fat rape seed-based diets for pigs. Influence on tissue _-tocopherol content, fatty acid profile and lipid oxidation. J. Sci. Food Agric. 2000;80:1625-1632.
9. Schalm OW, Jain NC, Caroll EJ. Textbook of veterinary haematology, 2nd Edition Published by Lea and Febiger, Philadelphia. 1975;129-250.
10. Lamb GM. Manual of veterinary laboratory techniques (Lamb, G.M. ed). CIBA-GEIGY, Kenya. 1981;102-115.
11. AOAC. Official methods of analysis. 17th ed. Association of Official Analysis Chemists, Washington DC; 2000.
12. Lopes-Virella MF, Stone P, Ellis S, Colwell JA. Cholesterol determination in high-density lipoproteins separated by three different methods. Clinical Chemistry. 1977;23:822-824.
13. Friedewald WT, Levy RI, Fredrickson DS. Estimation of the concentration of low-density lipoprotein cholesterol in plasma without use of the preparative ultracentrifuge. Clinical Chemistry. 1972;18(6):499-502.
14. AOAC. Association of Official Analytical Chemistry. Official Methods of Analysis 19th edition Washington D; 2010.
15. Minitab Statistical Package (ver. 16): Available:https://www.minitab.com/en-us/
16. Campbell GL, Salmon RE, Classen HL. Prediction of metabolizable energy of broiler diets from chemical analysis. Poultry Science. 1986;65(11):2126–2134. DOI:https://doi.org/10.3382/ps.0652126
17. Afsharmanesh MM, Sadeghi Ronizi B, Mehrabadi M. The Comparison of Natural Feed Additives (garlic and yogurt) with Antibiotic Growth Promoters on Broiler Performance; 1st national conference livestock and poultry industry of Golestan province. 2008;23- 25.
18. Raeesi M, Hoeini-Aliabad SA, Roofchaee A, ZareShahneh A, Pirali S. Effect of periodically use of garlic (*Allium sativum*) powder on performance and carcass characteristics in broiler chickens. World Academy of Science, Engine. Techno. 2010;68:1213-1219.
19. Mansoub HN, Nezhad MAM. The effects of using Thyme, Garlic and Nettle on performance, carcass quality and blood parameters. Annals of Biological Research. 2011;2(4):315-320.
20. Javandel F, Navidshad B, Seifdavati I, Pourrahimi GH, Baniyaghoub S. The favourite dosage of garlic meal as a feed additive in broiler chicken rations. Pakistan. Journal. Biological. Sciences. 2008;11:1746-1749.
21. Salah HE. Black cumin and garlic powder in poultry diets. World Poultry Broiler Nutrition. 2012;4019.
22. Aji SB, Ignatuius K, Ado AY, Nuttu JB, Abdulkarim A. Effect of feeding onions (*Allium cepa*) and garlic (*Allium sativum*) on some performance characteristics of broiler chickens. Research Journal of Poultry Science. 2011;4:22-27.
23. Mansoub NH. Comparative effects of using garlic as probiotic on performance and serum composition of broiler chickens. Annals of Biological Research. 2011;2: 486-490.
24. Kumar S, Sharadinma KC, Radhakrishna A. Effect of a garlic active based groeth promoter on growth performance and specific pathogenic intestinal microbial counts of broiler chicks. International Journal of Poultry Science. 2010;9:244-246.
25. Horton GMJ, Fennell MJ, Prasad BM. Effect of dietary garlic (*Allium sativum*) on performance, carcass composition and blood chemistry changes in broiler chickens. Can. J. Anim. Sci. 1991;71:939–942
26. Konjufca VH, Pesti GM, Bakalli RI. Modulation of cholesterol levels in broiler meat by dietary garlic and copper. Poult Sci. 1997;76:1264–1271.
27. Khan RU, NIkousefat Z, Tufarelli V, Naz S, Javdani M, Laudadio V. Garlic (*Allium sativum*) supplementation in poultry diets: Effect on Production and Physiology. World Poultry Science Association World's Poultry Science Journal. 2012;68:417-424.
28. Khan QSH, Hasan S, Sardar R, Anjum MA. Effects of dietary garlic powder on cholesterol concentration in native Desi laying hens. American Journal of Food Technology. 2008;3:207-213.
29. Ramakrishma RR, Platel K, Srinivasan K. In Vitro influence of species and spice-active principles on digestive enzymes of rat pancreas and small intestine. Nahrung. 2003;47:408-412.
30. Fasuyi AO, Aletor VA. Protein replacement value of cassava (*Manihot esculenta,* Crantz) leaf protein concentrate in broiler

starter: effect on performance, muscle growth, haematology and serum metabolites. International Journal of Poultry Science. 2005;4:339–349.
31. Javed M, Durrani F, Hafeez A, Khan RU, Ahmad I. Effect of aqeous extract of plant mixture on carcass quality of broiler chicks. ARPN Journal of Agricultural and Biological Science. 2009;4:37-40.
32. Ashayerizadeh O, Daster B, Shargh MS. Use of garlic (*Allium sativum*), black cumin seeds and wild mint (*Mentha longifolia*) in broiler chicken diets .Journal of Animal and Veterinary Advance. 2009;8:1860-1863.
33. Mahmood S, Hassan MM, Alam M, Ahmed F. Comparative efficacy of *Nigella sativa* and *Allium sativum* as growth promoters in broilers. International Journal of Agricultural and Biology. 2009;11:775-778.
34. Javandel F, Navidshad B, Seifdavati I, Pourrahimi GH, Baniyaghoub S. The favourite dosage of garlic meal as a feed additive in broiler chicken rations. Pakistan. Journal. Biological. Sciences. 2008;11:1746-1749.
35. Dieumou FE, Teguia A, Kuiate JR, Tamokou JD, Fouge NB, Dongmo MC. Effects of ginger (*Zingiber officinale*) and garlic (*Allium sativum*) essential oils on growth performance and gut microbial population of broiler chickens. Livestock Research for Rural Development. 2009;21(8).
36. Szigeti G, Palfi V, Nagy B, Ine E, Nagy G, Szmoleny G, Bago G, Radvanyi S. New type of immune stimulant to increase antibody production generated by viral and bacterial vaccines. Magyar Allatorvosok Lapja. 1998;120:719-721.
37. Ahsan-ui-Haq, Meraj KA, Rasool S. Effect of supplementary *Allium sativum* (garlic) and *Azidirachta indica* (Neem) leaves in broiler feeds on their blood cholesterol, triglycerides and antibody titre. International Journal of Agricultural and Biology. 1999;1:125-127.
38. Nidaullah H, Durrani FR, Ahmad S, Jan IU, Gul S. Aqueous extract from different medicinal plants as anticoccidial, growth promotive and immunostimulant in broilers. ARPN Journal of Agricultural and Biological Science. 2010;5:53-59.
39. Rahimi S, Zadeh T, Karimi MA, Omidbaigi R, Rokni H. Effect of the true herbal extracts on growth performance, immune system, blood factors and intestinal selected bacterial population in broiler chickens. Journal of Agricultural Science and Technology. 2011;13:527-539.
40. Chowdhurry SR, Chowdhurry SD, Smith TK. Effects of dietary garlic on cholesterol metabolism in laying hens. Poultry Science. 2002;81:1856-1862.
41. Canogullari S, Baylan M, Erdogan Z, Duzguner V, Kucukgul A. The effects of dietary garlic powder on performance, egg yolk and serum cholesterol concentration in laying quails. Czech Journal of Animal Science. 2010;55:286-293.
42. Qureshi AA, Din ZZ, Abuirmeileh N, Burger WC, Ahmed Y, Elson CE. Suppression of avian hepatic lipid metabolism by solvent extracts of garlic- Impact on serum lipids. Journal of Nutrition. 1983;113:1746– 1755.
43. Kamal Jamal Issa, Abo Omar JM. Effect of garlic powder on performance and lipid profile of broilers. Open Journal of Animal Sciences. 2012;2:62-68.
44. Prasad R, Rose MK, Virmani M, Garg SL, Puri JP. Lipid profile of chicken (*Gallus domesticus*) in response to dietary supplementation of garlic (*Allium sativum*). Int. J. Poult. Sci. 2009;8:270-276. DOI:10.3923/ ijps. 2009.270.276
45. Chi MS, Koh H, Steward TJ. Effects of garlic on lipid metabolism in rats fed cholesterol or lard. Journal of Nutrition. 1983;112:241-248.
46. Afzal M. Hassan RAH, El-kazini AA, Fattah RMA. *Allim sativum* in the control of atherosclerosis. Agricultural and Biological Chemistry. 1985;49:1187-1188. DOI: 10. 1271 /bbb1961.49.1187
47. Kim YJ, Jin SK, Yang HS. Effect of dietary garlic bulb and husk on the physiochemical properties of chicken meat. Poultry Science. 2009;88:398-405. DOI: 10.3382/PS.2008-00179

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/21924