Original Research Article

Garlic (*Allium sativum*) Powder as an Additive in Broilers (1-28days). Phase 1: Growth performance and Hypocholesterolemic Effects

ABSTRACT

Garlic cloves were purchased from the local market and made into powdery form by mincing and sun-drying. One hundred and ninety-two day old commercial broilers were randomly allotted to four treatments and four replicates. Garlic powder was introduced into the experimental broiler diets as an additive at $0gKg^{-1}$ (control diet), $2gKg^{-1}$, $3gKg^{-1}$ and $4gKg^{-1}$ inclusion levels in diets 1, 2, 3 and 4, respectively. The performance parameters in the experiment were progressively improved by increasing dietary garlic powder from $2gKg^{-1}$ up to $3gKg^{-1}$ and reduced thereafter when dietary garlic powder level was beyond $3gKg^{-1}$ garlic inclusion. The experimental birds were given feed and water *ad-libitum* while this phase lasted a period of 28 days (starter phase). The best growth performance and carcass characteristics (highest percentage dressed weight, percentage eviscerated weight, thigh, drumstick, and wing) were achieved at $2gKg^{-1}$ garlic addition. The investigated serum constituents indicated a facilitation of hypocholesterolemic functions from the group of birds fed with diet containing $2gKg^{-1}$ garlic addition. The inclusion level of garlic at $2gKg^{-1}$ in the present experiment appeared to be most suitable as an additive in broiler starter phase (1-28 days) diets capable of engendering growth performance while also exhibiting hypocholesterolemic tendencies.

Keywords: Performance parameters, carcass characteristics, hypocholesteremic 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. Garlic is considered as a plant with antibiotic, anticancer, antioxidant, immunomodulatory, anti-inflammatory, hypoglycemic and cardiovascular-protecting effects [1]. Other reported uses of garlic includes its tendency to lower serum and liver cholesterol [2], its effect as a supplement on production performance and carcass quality [3].

The key active ingredient in garlic, allicin (Fig. 1), is a powerful plant chemical which rapidly decomposes to several volatile organo-sulphur compounds with bioactivities [4]. Allicin is deactivated to diallyl disulphide (Fig. 2); a reason why minced garlic changes its aroma if not used immediately. Allicin has been suggested to be a powerful antibiotic and antifungal compound (phytoncide) which is used in some cases as home remedy to help speed recovery from strep throat or other minor ailments because of its antibiotic properties [4, 5].

When a clove of garlic is crushed, alliin, which is of the cyclo-oxygenase and lipoxygenase group of enzymes, is converted to its anti-microbial active form of allicin [5]. Allicin is a sulphur containing compound (thio-2-propene-1-sulfinic acid S-allyl ester) and its production from an odourless precursor alliin, is catalyzed by an enzyme, alliinase or alliin lyase and is responsible for the characteristic smell of garlic [6].

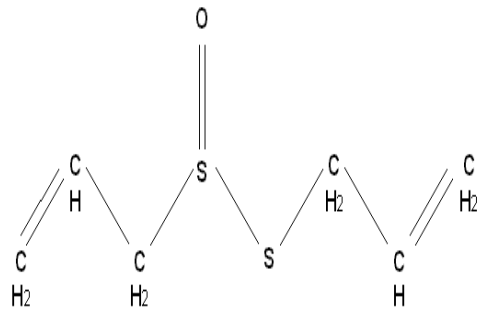

Fig. 1: Chemical structure of Allicin

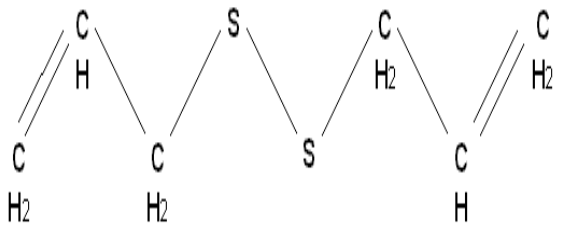

Fig. 2: Chemical structure of Diallyl disulphide

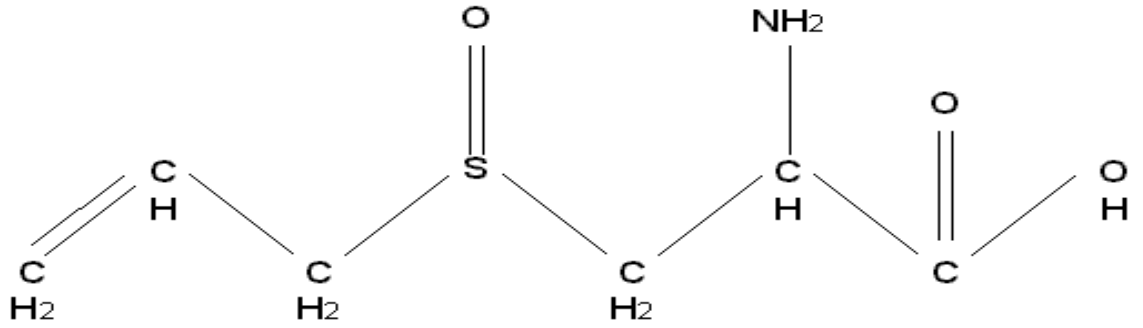

Fig. 3: Chemical structure of Alliin

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 [7] and occasional allergic reactions [8] are recognized. Garlic is not widely used as human food because it gives a repulsive odour and the taste is pungent [8].

Since monogastric animals are able to incorporate dietary components directly in their tissues [9], 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 on growth performance, carcass characteristics, haematological indices, 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, Ado Ekiti, a town in the southwest Nigeria in the rain forest zone on latitude 7^0 40' North of the equator and longitude 5^0 15' East of Greenwich Meridian with ambient temperature, 25-37^0c; 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 starter and finisher diets at $0gKg^{-1}$, $2gKg^{-1}$, $3gKg^{-1}$ and $4gKg^{-1}$ inclusion levels.

2.2 Experimental birds and diets

One hundred and ninety-two day old commercial broilers were randomly allotted to four treatments and four replicates. The chicks were fed on a standard commercial broiler starter diet until the 8th 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 8th to 28th day. Four diets were formulated for the starter phase which lasted for 28 days. 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 below.

2.3 Haematological Parameters

At the end of the feeding trial, two birds from each experimental treatment were randomly selected, weighed and sacrificed by severing the jugular vein and blood allowed to flow freely into labelled bottles one of which contained 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.

The Haemoglobin concentration (Hbc) was estimated using cyanomethaemoglobin method as described [10], 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 [11].

2.4 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 [12]. High density lipoproteins (HDLP) in the samples were separated by precipitation through adopted procedure [13]. Low density lipoprotein cholesterol (LDLC) in the samples was determined using the described relationship described [14].

2.5 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.

2.6 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 [15]. 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.

2.7 Statistical analysis

Data were subjected to analysis of variance (ANOVA) using Minitab Analytical Computer Package [16]. Duncan's Multiple Range Test was used to separate significant differences among the means and the separated mean values were compared where necessary at a level of $P<0.05$.

3. RESULTS AND DISCUSSION

3.1 Performance Characteristics of Broiler Chicks (0-28 Days)

The performance characteristics are displayed in Table 2. The metabolizable energy was calculated [17]. The average feed intake (AFI) value of birds on the diet supplemented with 2gKg^{-1} garlic was highest at 73.35±1.79 g/bird/day although similar (P>0.05) to the value of 72.41±0.68 g/bird/day obtained for birds on diet 3 with 3gKg^{-1} garlic supplementation. The lowest AFI value of 69.92±0.84g/bird/day was obtained for birds on diet 4 with 4gKg^{-1} garlic supplementation. The average weight gain (AWG) value of 44.17±0.34g/bird/day was highest for birds on 2gKg^{-1} garlic supplementation although similar (P>0.05) to 43.59±0.49g/bird/day obtained for birds on diet 3 (3gKg^{-1} garlic supplementation). The lowest (P>0.05) AWG value of 36.22g/bird/day was obtained for birds on 4gKg^{-1} garlic supplemented diet 4.

The optimum feed conversion ratio (FCR) of 1.66±0.03 was obtained for birds on diets 2 and 3 of 2gKg^{-1} and 3gKg^{-1} garlic supplementation, respectively. Likewise, the protein efficiency ratio (PER) of 2.59±0.05 was obtained for birds on both diets 2 and 3 of 2gKg^{-1} and 3gKg^{-1} garlic supplementation. The highest and poorest FCR value of 1.93±0.04 was obtained for birds on 4gKg^{-1} garlic diet although similar (P>0.05) to the value of 1.91±0.02 obtained for birds on the control diet without garlic. The poorest PER was also obtained for birds on 4gKg^{-1} at 2.23±0.05. This PER value was also similar (P>0.05) to the value of 2.26±0.02 obtained for birds on the control diet without garlic.

The highest feed intake values consistently obtained for birds on 2gKg^{-1} garlic supplemented diets at starter (0-28days) phase-corroborated with earlier studies on garlic supplementation in broilers. Improved feed intake up to 3gKg^{-1} garlic supplementation and subsequent reduction in feed intake were observed in some studies [18, 19]. The lowest feed intake values were obtained for birds on 4gKg^{-1} garlic supplemented diet and this still agreed with previous researchers [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. 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 2gKg^{-1} at the starter phase of broiler production agreed with previous studies [22, 24]. It was equally 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 [23].

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, others reported higher inclusion levels. For instance, it was concluded that the incorporation of garlic as feed additive at 3% level significantly enhanced growth and performance of broiler chicks without any side effects as detected by blood profile [25]. Some previous studies considered these parameters as controversial [26, 27] and could not trace any effect of garlic supplementation on the performance of broiler chicks.

Even though the protein efficiency ratio (PER) values of birds on 2gKg^{-1} garlic supplemented diets were higher but similar statistically with other values, evidence abound that garlic had beneficial effects on feed efficiency and growth of broiler chickens [28]. 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 Carcass Characteristics of Broilers (0-28 Days)

The highest significant ($P<0.05$) live weight value of 1322.0±8.50g was obtained for birds on 2gKg^{-1} garlic diet. Other live weight values were similar ($P>0.05$) at 1219.50±0.70g, 1257.0±25.5g and 1216.50±10.6g for birds on the control diet without garlic supplementation, 3gKg^{-1} garlic supplemented diet and 4gKg^{-1} garlic supplemented diet, respectively.

The dressed weight of 128.35±7.80% was also significantly highest ($P<0.05$) for birds on 2gKg^{-1} garlic supplemented diet and lowest at 93.40±8.5% for birds on 4gKg^{-1} garlic supplemented diet. Likewise, the eviscerated weight value of 116.90±9.90% obtained for birds on 2gKg^{-1} garlic diet was the highest but similar ($P>0.05$) to 114.25±31.80% obtained for birds on 3gKg^{-1} garlic supplemented diet. Birds on the control diet without garlic had the lowest eviscerated weight value of 81.50±71% but similar ($P>0.05$) to 88.95±99.7% obtained for birds on 4gKg^{-1} garlic supplemented diet.

Although there was no significant differences ($P>0.05$) in the mean values of thigh, birds on diet 2 with 2gKg^{-1} garlic supplementation had the numerically highest value of 140.75±6.72g/kg body weight and numerically lowest at 121.0±3.45g/kg body weight for birds on 4gKg^{-1} garlic supplementation. The average drumstick values of birds on diets with 2gKg^{-1} garlic supplementation were significantly higher ($P<0.05$) than other average drumstick values for birds on control diet and 4gKg^{-1} garlic supplemented diet at 69.00±1.42g/kg body weight and 66.00±2.12g/kg body weight, respectively. However, the average drumstick values of birds on 2gKg^{-1} and 3gKg^{-1} garlic supplemented diets were similar ($P>0.05$).

This trend continued for average values obtained for the weights of wings and neck on experimental birds. A significantly higher ($P<0.05$) wing value of 73.25±1.06g/kg body weight was obtained for birds on 2gKg^{-1} garlic diet although similar ($P>0.05$) to 69.75±2.48g/kg body weight obtained for birds on 3gKg^{-1} garlic diet. The mean weight of neck obtained for birds on 2gKg^{-1} garlic diet was highest at 68.50±4.95g/kg body weight but similar ($P>0.05$) to 61.00±2.83g/kg body weight and 57.00±2.83g/kg body weight obtained for birds on 3gKg^{-1} garlic diet and the control diet without garlic, respectively.

The back fat had the lowest value of 0.45g/kg body weight for birds on 2gKg^{-1} garlic diet albeit similar ($P>0.05$) to 0.50±0.14g/kg body weight and 0.60±0.02g/kg body weight obtained for birds on 3gKg^{-1} and 4gKg^{-1} garlic diets, respectively.

The live weight, dressed weight and eviscerated weight values for birds on 2gKg^{-1} and 3gKg^{-1} garlic supplemented diets had the highest value. However, birds on diet 2 (2gKg^{-1}) had the best result but the lowest values for these carcass cuts were consistently obtained for birds on 4gKg^{-1} garlic supplemented diets. The findings of the current study agreed with a previous study [30] who found that feed intake and FCR, body weight and carcass quality (dressing percentage, breast weight and leg weight) were improved in a 35day 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 [31].

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 [32] and carcass characteristics in term of percentage of carcass, small intestines, proventriculus, gizzard, liver and abdominal fat [33].

3.3 Relative Organ Weight at 0-28days

The relative organ weights were similar (P>0.05) for all experimental birds on both control diet and garlic supplemented diets.

However, the numerical values of all the measured organs such as liver, heart, spleen, and gizzard were higher for the birds on $2gKg^{-1}$ garlic supplemented diet than for other diets. The mean values of 28.50±2.12g/kg body weight, 8.00±0.12g/kg body weight, 2.50±0.71g/kg body weight and 37.00±1.41g/kg body weight for liver, spleen and gizzard, respectively obtained for birds on the $2gKg^{-1}$ garlic diet were numerically greater than values obtained for other birds on other diets.

All investigated organs (liver, heart, spleen and gizzard) had similar values corroborating with most previous studies [23, 26, 32, 33, 34].

3.4 Haematological Indices of Birds on Garlic Supplemented Diets (0-28days)

Except for mean cell haemoglobin, all haematological parameters investigated had similar values (P>0.05) for experimental birds on all diets including the parameters examined for the birds on the control diet without garlic supplementation.

The packed cell volume (PCV) ranged from 29.00±2.83% in the birds on $2gKg^{-1}$ garlic supplemented diet to 22.00±7.07% in the birds on the control diet without garlic supplementation. The haemoglobin concentration (Hbc) had the highest albeit similar (P>0.05) value of 8.68±0.35g/100ml for the birds on the control diet without garlic supplementation and the lowest value of 5.95±g/100ml for the birds on the $4gKg^{-1}$ garlic supplemented diet.

The red blood cell (RBC) value of $1.49±0.16 \times 10^6$/ mm obtained for birds on $2gKg^{-1}$ garlic supplemented diet was highest but similar (P>0.05) to other values while $1.16±0.01\times10^6$/mm obtained for birds on the control diet without garlic supplementation was the lowest.

The total white blood cell (TWBC) had the highest value of $11.00±4.24\times10^9$/L for birds on the control diet and lowest value of $4.00±0.34 \times 10^9$/L for birds on $2gKg^{-1}$ garlic supplemented diet. However, all TWBC values obtained for experimental birds were similar (P>0.05).

The neutrophil had 29.00±1.41% and 29.00±9.90% as the highest average values for birds on the control diet without garlic supplementation and diet 4 of $4gKg^{-1}$ garlic supplementation, respectively. The lowest value of 23.00±4.24% was obtained for birds on $2gKg^{-1}$ garlic supplemented diet. All neutrophil values obtained for experimental birds were similar (P>0.05).

The lymphocytes were highest at 61.00±6.41% for birds on the control diet without garlic supplementation but similar (P>0.05) to all other values at 51.00±9.90%, 51.00±7.07% and 51.00±15.56% for birds on diets 2, 3 and 4, respectively ($2gKg^{-1}$, $3gKg^{-1}$ and $4gKg^{-1}$ garlic supplementation, respectively). The monocytes had 11.00±1.41% as the highest value but also similar (P>0.05) to all other values at 7.00±1.41%, 9.00±1.41% and 9.00±1.41% obtained for birds on diets 2, 3 and 4 of $2gKg^{-1}$, $3gKg^{-1}$ and $4gKg^{-1}$ garlic supplementation, respectively.

The eosinophil value of 7.00±1.46% was the highest for birds on the control diet without garlic but similar (P>0.05) to other values of 5.00±1.41%, 5.00±1.41% and 6.00±4.24% for birds on $2gKg^{-1}$, $3gKg^{-1}$ and $4gKg^{-1}$ garlic supplemented diets, respectively.

The basophil values for all experimental birds on all diets were similar (P>0.05) with a range of 2.00±2.83% for birds on the control diet without garlic and 1.00±1.41% for birds on $4gKg^{-1}$ garlic supplemented diet.

The mean cell haemoglobin concentration (MCHC) also had similar values (P>0.05) with a highest range of 4.19±1.50% for birds on the control diet without garlic supplementation and a lowest range of 2.48±0.13% for birds on $3gKg^{-1}$ garlic supplemented diet.

The mean cell volume (MCV) had similar value (P>0.05) for all experimental birds with a highest range of 200.26±30.05 μm^3 for birds on $4gKg^{-1}$ garlic supplemented diet and a lowest range of 188.60±31.01 μm^3 for birds on $3gKg^{-1}$ garlic supplemented 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 [35, 36, 37, 38].

3.5 Serum metabolites of chickens (0-28days)

The total cholesterol was significantly higher (P>0.05) at 5.62±0.39g/dl for birds on the control diet without garlic supplementation. The cholesterol contents of 3.36±0.18g/dl, 3.64±0.30g/dl and 3.74±0.04g/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) and low density lipoprotein (LDL) values followed the same pattern for total cholesterol contents of experimental birds. The HDL value of 3.76±0.16g/dl was significantly higher (P>0.05) for birds on the control diet without garlic powder than for other HDL values while other HDL values of 1.77±0.14g/dl, 1.99±0.01g/dl and 1.87±0.19g/dl were similar (P>0.05) for birds on $2gKg^{-1}$, $3gKg^{-1}$ and $4gKg^{-1}$ garlic supplemented diets, respectively. Ditto for LDL values, the LDL value of 4.41±0.37g/dl was significantly higher (P>0.05) for birds on the control diet without garlic than other LDL values. LDL values of 1.21±0.28g/dl, 1.26±0.45g/dl and 1.40g/dl were similar (P>0.05) for birds on $2gKg^{-1}$, $3gKg^{-1}$ and $4gKg^{-1}$ garlic supplemented diets, respectively.

The total serum protein value of 3.09±0.01g/dl obtained for birds on the $2gKg^{-1}$ garlic supplemented diet was the highest but similar (P>0.05) to 3.07±0.12g/dl and 3.02±0.10g/dl obtained for birds on $3gKg^{-1}$ and $4gKg^{-1}$ garlic supplemented diets. Birds on the control diet without garlic had the lowest significant (P>0.05) total serum protein of 2.38±0.08g/dl.
The albumin levels of 2.02±0.06g/dl and 2.08±0.01g/dl were similar (P>0.05) for birds on $2gKg^{-1}$ and $3gKg^{-1}$ garlic supplemented diets and the Albumin levels of 2.59±0.01g/dl and 2.73±0.05g/dl were similar (P>0.05) for birds on the garlic free diets and $4gKg^{-1}$ garlic supplemented diets. The lowest significant (P>0.05) albumin level of 2.59±0.01g/dl was obtained for birds on the control diet without garlic supplementation.

The globulin level of 3.48±0.08g/dl was the lowest for birds on the control diet without garlic, but birds on $2gKg^{-1}$, $3gKg^{-1}$ and $4gKg^{-1}$had similar (P>0.05) globulin values of 4.15±0.05g/dl, 4.08±0.03g/dl and 4.00±0.01g/dl, respectively.
The albumin/globulin ratio of 0.48±1.20g/dl was the lowest for birds on $2gKg^{-1}$ garlic supplemented diet, but similar (P>0.05) to albumin/globulin levels of 0.74±0.13g/dl, 0.51±0.03g/dl and 0.68±3.10g/dl obtained for birds on the control diet without garlic supplementation, $3gKg^{-1}$ and $4gKg^{-1}$ respectively.

The total cholesterol (TC) contents were significantly reduced in serum metabolites of all birds on the garlic supplemented diets at starter phases of this broiler experiment. The anti-cholestolemic effects of garlic are well documented. Several reports suggested that varying supplementary levels of garlic in poultry birds has decreased egg yolk cholesterol of laying hens [39, 40], reduced plasma cholesterol in broilers fed garlic at 10,000mg/kg in 35 days treatment [26] and reduced serum cholesterol concentration in white Leghorn pullets [2].

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 [2, 22, 41]. 28-41% reduction in low density lipoprotein (LDL) cholesterol in an experimental diet containing 3.8% garlic paste had been reported [2]. Reductions in total cholesterol, LDL-cholesterol and triglycerides had been reported when broilers were supplemented with 1g/kg garlic [22]. It was also reported that garlic powder decreased total cholesterol, triglycerides and low density lipoprotein [41].

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 [42]. 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 [2, 43] and 3-hydroxyl-3-methyl-glutaryl-CoA (HMG-CoA) reductase [44]. It has also been reported that polyunsaturated fatty acids prevent atherosclerosis through the formation of cholesterol esters [44]. 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 [45].

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.

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

Ingredient	Quantity
Maize (9% CP)	55.00
Soyabean meal(45.0% CP)	37.60
Fish meal(68%CP)	2.00
Palm oil	1.00
Bone meal	2.50
Oyster shell	0.50
Salt	0.50
DL-methionine	0.20
L-lysine	0.20
Premix*	0.50
Total	100.00
Calculated:	
Crude protein (%)	23.30
ME(kcal/kg)	2937.00
Crude fibre(%)	3.96
Ether extract	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) [17].*

There are 4 diets that are isocaloric and isonitrogenous: Diet 1 is the control diet without garlic powder as additive, diets 2, 3 and 4 have 2.0gKg^{-1}, 3.0gKg^{-1} and 4.0gKg^{-1} garlic powder additives, respectively

Table 2. Production performance of broiler chicken fed garlic powder from 0-28 days of age (starter phase)

	Treatments			
	1	2	3	4
	Supplementary garlic (gKg^{-1})			
Parameters	**0 (Control)**	**2.0**	**3.0**	**4.0**
Average Feed Intake (g/bird/day)	70.96±0.57[ac]	73.35±1.79[b]	72.41±0.68[ab]	69.92±0.84[c]
Average Weight Gain (g/bird/day)	37.19±0.20[a]	44.17±0.34[b]	43.59±0.49[b]	36.22±0.54[c]
Feed Conversion Ratio (FCR)	1.91±0.02[a]	1.66±0.03[b]	1.66±0.03[b]	1.93±0.04[a]
Protein Efficiency Ratio (PER)	2.26 ±0.02[a]	2.59 ±0.05[b]	2.59±0.05[b]	2.23±0.05[a]
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).

Table 3. Carcass trait of broiler chicken fed garlic powder from 0-28 days of age (starter phase)

	Treatments			
	1	2	3	4
		Supplementary garlic (gkg^{-1})		
Parameters	**0 (Control)**	**2.0**	**3.0**	**4.0**
Live weight(g)	1219.50±0.70[a]	1322.00±8.50[b]	1257.00±25.50[a]	1216.50±10.60[a]
Dressed weight (%)	94.80±11.30[a]	128.35±7.80[b]	118.90±15.60[c]	93.40±8.50[a]
Eviscerated weight (%)	81.50±7.10[a]	116.90±9.90[b]	114.25±31.80[b]	88.95±99.70[a]
Thigh (g/kg body wt)	128.25±6.01	140.75±6.72	130.00±3.54	121.00±3.54
Drumstick (g/kg body wt)	69.00±1.42[a]	132.25±11.67[b]	122.00±10.61[b]	66.00±2.12[a]
Back (g/kg body wt)	289.00±28.28	314.50±24.75	284.50±4.95	269.50±7.78
Shank (g/kg body wt)	26.50±4.24	29.25±1.06	25.50±0.71	25.50±4.24
Wing(g/kg body wt)	53.25±4.60[a]	73.25±1.06[b]	69.75±2.48[b]	51.50±2.12[a]
Head (g/kg body wt)	45.00±5.66	48.50±2.12	47.50±2.12	44.00±7.07
Neck (g/kg body wt)	57.00±2.83[ab]	68.50±4.95[b]	61.00±2.83[ab]	54.50±0.71[a]
Back fat (g/kg body wt)	2.15±0.21[a]	0.45±0.21[b]	0.50±0.14[b]	0.60±0.02[b]

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

Table 4. Relative organ traits (g/kg body weight) of broiler chicken fed garlic powder from 0-28 days of age (starter phase)

	Treatments			
	1	2	3	4
		Supplementary garlic (gKg^{-1})		
Parameters	**0 (Control)**	**2.0**	**3.0**	**4.0**
Liver	24.50±3.54	28.50±2.12	26.50±2.12	22.00±2.83
Heart	7.50±0.71	8.00±0.12	8.00±0.14	7.00±0.50
Spleen	2.00±0.05	2.50±0.02	2.00±0.01	1.50±0.05
Gizzard	29.50±0.71	37.00±1.41	35.50±0.71	30.00±4.24
Lungs	7.50±0.71	8.00±1.41	8.00±1.41	8.00±1.41

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

Table 5. Haematology of broiler chicken fed garlic powder from 0-28 days of age (starter phase)

	Treatments			
	1	2	3	4
	Supplementary garlic(gKg^{-1})			
Parameters	**0 (control)**	**2.0**	**3.0**	**4.0**
PCV (%)	22.00 ± 7.07	29.00± 2.83	27.00± 1.41	23.00± 8.49
HBc (g/100ml)	8.68± 0.35	7.71± 0.39	6.69 ± 0.20	5.95 ± 2.10
RBC ($x10^6/mm^3$)	1.16 ± 0.01	1.49 ± 0.16	1.45 ± 0.16	1.29 ± 0.42
TWBC ($x\ 10^9/L$)	11.00 ± 4.24	4.00± 0.34	4.50 ± 0.71	5.00 ± 0.12
Neutrophil (%)	29.00± 1.41	23.00± 4.24	26.00± 2.83	29.00± 9.90
Lymphocytes (%)	61.00± 6.41	51.00± 9.90	51.00± 7.07	51.00± 8.46
Monocytes (%)	11.00 ± 1.41	7.00± 1.41	9.00± 1.41	9.00± 1.41
Eosinophil (%)	7.00± 1.46	5.00± 1.41	5.00± 1.41	6.00± 4.24
Basophil (%)	2.00 ± 2.83	1.52 ± 1.50	1.40 ± 1.12	1.00± 1.41
MCH(pg)	$7.51±0.25^a$	$5.19±0.28^b$	$4.66±0.52^b$	$4.60±0.14^b$
MCHC (%)	4.19±1.50	2.68±0.40	2.48±0.13	2.95±2.00
MCV(μm^3)	190.67±31.39	196.69±39.52	188.60±31.01	200.26±30.05

Mean ± Standard deviation; (a, b) Means in the same row with the different superscriptare 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 6. Serum analyses of broiler chicken fed garlic powder from 0-28 days of age (starter phase)

	Treatments			
	1	2	3	4
	Supplementary garlic(gKg^{-1})			
Parameters	**0 (Control)**	**2.0**	**3.0**	**4.0**
Total Cholesterol (mmol/l)	5.62 ± 0.39[a]	3.36± 0.18[b]	3.64± 0.30[b]	3.74± 0.04[b]
HDL (mmol/l)	3.76± 0.16[a]	1.77± 0.14[b]	1.99± 0.01[b]	1.87 ± 0.19[b]
LDL (mmol/l)	4.41 ± 0.37[a]	1.21 ± 0.28[b]	1.26 ± 0.45[b]	1.40 ± 0.26[b]
Triglycerides	0.44 ± 0.16[a]	0.16± 0.18[b]	0.16 ± 0.10[b]	0.24 ± 0.07[b]
Total Serum Protein(g/dl)	2.38± 0.04[a]	3.09± 0.01[b]	3.07± 0.02[b]	3.02± 0.01[b]
Albumin (g/dl)	2.59± 0.01[a]	2.02± 0.06[b]	2.08± 0.01[c]	2.73± 0.05[c]
Globulin (g/dl)	3.48± 0.08[b]	4.15± 0.05[b]	4.08± 0.03[a]	4.00± 0.01[a]
Albumin/Globulin ratio	0.74± 0.13	0.48± 1.20	0.51± 0.03	0.68± 3.10

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

.

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 (highest live weight, dressed weight and eviscerated weight). Virtually all investigated organs except lungs had similar values among the garlic supplemented diets and control in dictating that organs were not affected by the addition of garlic powder in broiler diets.

Haematological parameters were not significantly affected by garlic supplementation in broiler diets. Survivability of the broilers could be enhanced by supplementation in broiler diets. There was ample evidence of anti-cholesterolemic properties when garlic powder was added as dietary supplements in broiler rations as a result of the significant reduction in the contents of total cholesterol, low density lipoprotein and triglycerides in the sera collected from birds that were raised on garlic supplemented diets. The investigated blood serum parameters indicated that garlic powder in broiler diets exhibited both hypocholesterolemic and hypolipidemic properties.

Birds on $2gKg^{-1}$ garlic supplemented diets had the best net returns per bird produced and ultimately the most profitable ration in the present study. There is also 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 poorer growth performance, sub-optimal blood evaluation indices and poor economic production indices.

It is evident that adding garlic beyond 3gKg^{-1} inclusion level in broiler diet (4gKg^{-1}) had a diminishing return effect because the birds on such diet had the poorest performance, sub-optimal blood evaluation indices and non-economic production indices.

References

1. Reuter HD, Koch HP, Lawson LD. Therapeutic Effects and Applications of Garlic and its Preparations. In: Garlic: The Science and Therapeutic Application of Allium sativum L. and Related Species. 1996; Koch, H.P. and L.D. Lawson (Eds.). Williams and Wilkins, Baltimore, MD., pp: 135-213.
2. 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.
3. Tekeli A, Çelik L, Kutlu HR, Gorgulu M. Effect of dietary supplemental plant extracts onperformance, carcass characteristics, digestive system development, intestinal microflora andsome blood parameters of broiler chicks. 2006; XII European Poultry Conference, Italy.
4. Chang KJ, Cheong SH. Volatile organosulfur and nutrient compounds from garlic by cultivating areas and processing methods. Fed. Am. Soc. Exp. Bio. J. 2008; 22: 1108.2.
5. Metwally MAA. Effects of Garlic (*Allium sativum*) on Some Antioxidant Activities in Tilapia Nilotica (*Oreochromisniloticus*). World Journal of Fish and Marine Sciences. 2009; 1(1): 56-64.
6. Yeh YY, Liu L. Cholesterol lowering effect of garlic extracts and organosulphur compounds: Human and animal studies. J. Nutr. 2001; 131: 989S- 993S.
7. Mader FH. Treatment of hyperlipidemia with garlic-powder tablets. Evidence from the German Association of General Practitioners' multicentric placebo-controlled double-blind study. *Arzneimforsch*. 1990; 40(10):11111116
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. 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.
10. Schalm OW, Jain NC, Caroll EJ. Textbook of Veterinary Haematology, 2nd Edition Published by Lea and Febiger, Philadelphia. 1975; Pp. 129-250.
11. Lamb GM Manual of veterinary laboratory techniques (Lamb, G.M. ed). CIBA-GEIGY, Kenya. 1981; pp102-115
12. AOAC. Official Methods of Analysis. 17th ed. Association of Official Analysis Chemists, Washington DC. 2000
13. Lopes-Virella M.F., Stone P., Ellis S., Colwell J.A. (1977). Cholesterol determination in high-density lipoproteins separated by three different methods. Clinical Chemistry 23:822-824.
14. 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
15. AOAC. Association of Official Analytical Chemistry. Official Methods of Analysis 19th edition Washington D. 2010
16. Minitab Statistical Package (ver. 16): https://www.minitab.com/en-us/
17. Campbell GL, Salmon RE, Classen HL. Prediction of metabolizable energy of broiler diets from chemical analysis. Poultry Science. 1986;65(11):2126–2134. https://doi.org/10.3382/ps.0652126
18. Raeesi M, Hoeini-Aliabad SA, Roofchaee A, Zare Shahneh 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. 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.
23. 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
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. Elagib A, El-Amin WIA, Elamin KM, Malik HEE. Effect of Dietary Garlic (Allium sativum) Supplementation as Feed Additive on Broiler Performance and Blood Profile. *Journal of Animal Science Advances*. 2013; 3(2), 58-64.
26. Horton GMJ, Fennell MJ, Prasad BM. Effect of dietary garlic (*Alliumsativum*) on performance, carcass composition and blood chemistry changes in broiler chickens. *Can. J. Anim. Sci*. 1991; 71:939–942
27. Konjufca VH, Pesti GM, Bakalli RI. Modulation of cholesterol levels in broiler meat by dietary garlic and copper. Poult Sci. 1997; 76:1264–1271.
28. 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
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. 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
31. 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
32. 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.
33. 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)
34. 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
35. 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
36. 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
37. 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.
38. Chowdhurry SR, Chowdhurry SD, Smith TK. Effects of dietary garlic on cholesterol metabolism in laying hens. Poultry Science. 2002; 81: 1856-1862
39. 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
40. 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
41. Prasad R, Rose MK, Virmani M, Garg SL, Puri JP. Lipid profile of chicken (*Gallusdomesticus*) in response to dietary supplementation of garlic (*Allium sativum*). Int. J. Poult. Sci. 2009; 8: 270-276. doi:10.3923/ ijps. 2009.270.276

42. 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
43. 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
44. 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