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Effect of Garlic (Allium Sativum) Supplementation on Growth Performance and Serum Biochemistry of Broiler Chicks

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Abstract

The current study was conducted in the poultry shed of Livestock Research & Development, Khyber Pakhtunkhwa, Peshawar, Pakistan. A total of 120, day-old straight run broilers were procured from Big Bird Pvt. Ltd. The study was comprised of four experimental groups (G.S-0%, G.S-0.3%, G.S-0.6%, G.S-0.9%) having three replicates in each group with ten birds per replicate. Powdered garlic was supplemented @ 0, 0.3, 0.6 and 0.9% to different experimental groups in their basal diet. Zero level was kept as control group. Dietary intake, weight gain and feed conversion ratio (FCR) along with serum biochemical profile of birds were studied. The data in respect of feed intake, weight gain and feed conversion ratio were recorded for each week whereas serum biochemical profile was determined after the completion of the research trial. Dietary intake, was found statistically similar during all the four weeks and overall basis. Weight gain and FCR were statistically not different during the 1st three weeks of research trial whereas significantly different ($p \leq 0.05$) at 4th week and also for overall growth performance in terms of above-mentioned parameters. Significantly improved weight gain was observed for treatment group (G.S-0.9%) whereas significantly improved FCR was found for group (G.S-0.6%) as compared to control group. Overall antibody titer against Newcastle disease was non-significant among the experimental groups except G.S-0.6% which was statistically greater ($p \leq 0.05$) than control. As far as, antibody titer against infectious bursal disease (IBD) is concerned, experimental group (GS-0.9%) shown significantly improved ($p \leq 0.05$) antibody titer in comparison to other experimental groups.

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Garlic supplementation has shown positive impact on serum biochemical profile. Significantly lowered total serum cholesterol and triglycerides levels were recorded for group (GS-0.6%) as compared to other groups. Garlic supplementation @ 0.6% in basal diet is recommended for better and economic production in meat type birds.

Keywords: Broiler; Garlic; feed supplementation; Immunity; Economics.

1. Introduction

Secondary and alternate medicinal practices are on rise in the broiler production in the developing countries [1]. Extensive use of antimicrobial drugs for growth promotion in broiler production is currently facing grave condemnation and has global reservations of their residual effects and drug resistance in the end users [2, 3]. The use of antimicrobial for growth promotion has also been banned in many countries to cope the hazardous effects caused by these drugs [4]. These limitations of antibiotic based growth promoters lead to the explore alternate elements that could exterminate these short comings. Recently, an increase in the use of probiotics, prebiotics, synbiotics, enzymes and medicinal plants as natural feed supplements have been observed in poultry diet [5, 6]. Research studies have identified positive impact of different herbs and their by-products' supplementation on control of various pathogens and minimizing the residual effects of drugs which would have been used on the other hand for treating various pathogenic ailments in broiler production [7-9].

Fresh garlic (Allium sativum), has been used conventionally for years to cure an extensive range of diseases, including respiratory ailments, ulcers, gastro-intestinal disturbances and skin diseases [10]. Allium species are rich in natural alkaloids including allicin, allin, ajoene, and diallyl sulphide sallylcysteine. These alkaloids reveals antiseptic, anti-microbial, anti-inflammatory, anti-parasitic and immune-modulatory effects [11, 12]. Additionally, garlic has also been reported to possess hepato-protective, anti-cancerous and chemo-preventive activities [13]. Furthermore, garlic is rich source of sweet-smelling oils, which have positive impact on the functions of digestive and respiratory systems when inhaled into the lungs and air sacs of birds. Garlic has also been reported for its strong anti-oxidative nature [14]. Keeping in view the above-mentioned evidences, the current trial was conducted to evaluate the role dietary supplementation of powdered garlic on feed intake, weight gain, FCR, serum biochemical profile and immunity in meat type of birds.

2. Materials and Methods

The present experimental trial was carried out in the poultry shed of Livestock Research & Development, Khyber Pakhtunkhwa, Pakistan. Before commencement of trial, the shed and equipment were properly scrubbed, washed and disinfected. The experimental trial continued for a period of thirty-five days (five weeks) with one-week brooding period prior to garlic supplementation in feed. A total of 120, day-old straight run broilers were procured from Big Bird Pvt. Ltd., Pakistan. The study was comprised of four experimental groups (G.S-0%, G.S-0.3%, G.S-0.6%, G.S-0.9%) having three replicates in each group with ten chicks per replicate. Dietary supplementation of garlic @ 0, 0.3, 0.6 and 0.9% were investigated. Zero level was kept as control group. Raw garlic was bought from local market. The garlic was dried completely in sunlight and then ground

using electrical grinder with 1mm sieve. Clean and fresh water availability was ensured ad libitum round the clock. Light was provided for 24 hours a day. Chicks were fed with control experimental diet for first seven days (one week) during the brooding period and then were allocated to their respective treatment group randomly. Before allocating the chicks to experimental groups, chicks (ten chicks/replicate) were weighed and recorded as their initial weights.

2.1. Parameters Recorded

Feed Intake: Feed intake was recorded on daily basis for each group. The amount of feed being refused, was subtracted from that offered. The data were recorded in grams.

Body Weight Gain: Gain in body weight was recorded on weekly basis by deducting the initial weight of each replicate from final weight each week. The data were recorded in grams.

Feed conversion ratio: Valve for FCR was measured for each replicate at the end of each experimental week by using the following equation;

Feed conversion ratio: $$\frac{\text{Units of feed consumed (g)}}{\text{Units of weight gained (g)}}$$

Serum Biochemistry: Blood samples were aseptically collected from brachial vein of two chicks from each replicate at the end of experimental period in gel clot activation tubes. Serum was separated by centrifugation at 4000rpm and serum samples were subjected to biochemical profile tests. Chem-o-test Vet, Semi-auto chemistry analyzer by BioGen Technologies, Germany was used for serum tests. Total serum protein, globulin, albumen, total cholesterol and triglycerides were determined in each sample.

Antibody titers against common viral disease of broilers i.e. Newcastle disease (ND) and infectious bursal disease (IBD) were measured through haemagglutination inhibition test and enzyme linked immunosorbent assay respectively. Blood was collected through standard protocols on 35^{th} day of the experiment. Five birds per replicate were screened for antibody titers. For detection of antibody titer against IBD, ELISA kit Affini Tech. limited USA (IBD 0200) was used according to the manufacturer's protocol at Viral Vaccine Section Veterinary Research Institute, Peshawar.

2.2. Data Analysis

Data analyses were made through statistical package SPSS (version 27.0). Means were compared through one way ANOVA. Significant difference among the means were separated through DMR test at alpha 0.05 [15].

3. Results

Findings of the current trial in connection with growth performance in terms of dietary intake, weight gain and FCR as well as serum profile and immune status of broiler birds are produced in the following paras.

3.1 Effect of dietary supplementation of garlic powder on growth performance during the course of experimental trial

Growth performance in terms of gain in live body weight & FCR and diet intake were found non-significantly different ($p \geq 0.05$) during 1st week of the trial (Table, 01). Highest intake of feed was recorded for control group (2269.33 g) followed by GS-0.3% (1995.33 g), G.S-0.6% (1900.00 g) and then G.S-0.9% (1673.33 g). Higher weight gain was recorded for experimental group supplemented with 0.9% garlic powder (2967.30 g) followed by G.S-0.6% (2878.67 g), control group (2752.52 g) and GS-0.3% (2715.43 g). Likewise feed intake and weight gain, non- significant difference ($p \geq 0.05$) was recorded for feed efficiency during 1st week of the trial. Better feed efficiency was recorded for group supplemented with 0.9% garlic powder (0.58) followed by group G.S-0.6% (0.65), G.S-0.3% (0.74) and then control group (0.83).

Average intake of feed, gain in weight and FCR were found significantly similar ($p \geq 0.05$) among different treatment groups during second week of the trial (Table, 01). Greater feed intake was recorded for experimental group G.S-0.6% (5878.67g), followed by G.S-0.9% (5755.33 g), G.S-0.3% (5750.67 g) and then control group (5687.0 g). Non- significantly higher body weight gain was recorded for experimental group G.S-0.3% (6385.33 g), followed by G.S-0.6% (6316.0 g), G.S-0.9% (6224.0 g) and then control group (6107.0 g). Better feed conversion ratio was recorded for group G.S-0.3% (0.90) followed by G.S-0.6% and G.S-0.9% with similar value (0.93) and then control group (0.94).

During third week of experimental trial, average intake of feed, gain in weight and FCR were found non-significantly different (Table, 01). Higher feed intake was observed for control group (9210.0 g), followed by experimental group G.S-0.6% (9138.67 g), G.S-0.3% (9127.33 g and then G.S-0.9% (8486.67 g). Average body weight gain was higher for group G.S-0.6% (6379.33 g), followed by control group (6318.67 g), G.S-0.3% (6181.33 g) and then G.S-0.9% (5942.33 g). Feed utilization efficiency was found non-significantly different for all the experimental groups with better FCR noted for groups G.S-0.6% and G.S-0.9% followed by control group and then G.S-0.3%.

During fourth week of the experimental trial, average intake of feed, gain in weight and FCR were found significantly different ($p \leq 0.05$) for treatment groups in comparison to control group. Significantly greater ($p \leq 0.05$) feed intake was observed for experimental group G.S- 0.9% (12926.0 g) as compared to other experimental groups and control group. Non- significant difference was recorded for other three experimental groups with highest feed take been noted for G.S-0.3% followed by G.S-0.6% and then control group. Average gain in weight for chicks in control group was significantly ($p \leq 0.05$) inferior (3681.33 g) during the fourth week of experimental trial as compared to other treatment groups with highest weight gain been recorded for group G.S-0.9% (7332.33 g) followed by G.S-0.6% (7155.33 g) and then G.S- 0.3% (6441.33 g). Feed conversion

ratio was found statistically improved ($p \leq 0.05$) for the treatment groups in comparison to control one with non-statistical ($p \geq 0.05$) variations among each other.

Overall feed intake was found non-significantly different for all the experimental groups during the period of experimental trial. Greater feed intake was recorded for experimental group G.S- 0.9% (28841.33 g), followed by G.S-0.6% (28719.33 g), G.S-0.3% (28680.67 g) and then control group (28359.67 g). Average body weight gain of all the three experimental groups supplemented with garlic powder was significantly greater ($p \leq 0.05$) than chicks in control group (18859.52 g) with non-significant differences among each other. Highest weight gain was recorded for experimental group G.S-0.6% (22729.33 g), followed by G.S-0.9% (22465.97 g) and then G.S-0.3% (21723.43 g). Significantly improved ($p \leq 0.05$) overall feed efficiency was recorded for experimental groups supplemented with garlic powder in different proportions as compared to control group with highest FCR valve of 1.50. Feed efficiency for all the three experimental groups was found non-significant among each other with arithmetic differences in the current study. Better FCR value was recorded for G.S-0.6% (1.26), followed by G.S-0.9% (1.28) and then G.S-0.3% (1.32) in this trial.

Table 01: Effect of garlic supplementation on growth performance during the course of experimental trial.

Week	Group	Feed Intake (g)	Weight Gain (g)	Feed Conversion Ratio
1st Week	GS-0%	2269.33	2752.52	0.83
	GS-0.3%	1995.33	2715.43	0.74
	GS-0.6%	1900.00	2878.67	0.65
	GS-0.9%	1673.33	2967.30	0.58
	P. Value	**0.272**	**0.840**	**0.189**
2nd Week	GS-0%	5687.00	6107.00	0.94
	GS-0.3%	5750.67	6385.33	0.90
	GS-0.6%	5878.67	6316.00	0.93
	GS-0.9%	5755.33	6224.00	0.93
	P. Value	**0.961**	**0.835**	**0.975**
3rd Week	GS-0%	9210.00	6318.67	1.45
	GS-0.3%	9127.33	6181.33	1.47
	GS-0.6%	9138.67	6379.33	1.43
	GS-0.9%	8486.67	5942.33	1.43
	P. Value	**0.454**	**0.387**	**0.424**
4th Week	GS-0%	11193.33^{a}	3681.33^{a}	3.07^{a}
	GS-0.3%	11807.33^{a}	6441.33^{b}	1.84^{b}
	GS-0.6%	11802.00^{a}	7155.33^{b}	1.65^{b}
	GS-0.9%	12926.00^{b}	7332.33^{b}	1.76^{b}
	***P. Value**	**0.013**	**0.000**	**0.000**
Overall	GS-0%	28359.67	18859.52^{a}	1.50^{a}
	GS-0.3%	28680.67	21723.43^{b}	1.32^{b}
	GS-0.6%	28719.33	22729.33^{b}	1.26^{b}
	GS-0.9%	28841.33	22465.97^{b}	1.28^{b}
	***P. Value**	**.373**	**0.001**	**0.000**

Means with different superscripts in columns are significantly different at α 0.05

GS-0%= Garlic Supplementation at zero level, GS-0.3%= Garlic Supplementation at 0.3%

GS-0.6%= Garlic Supplementation at 0.6%, GS-0.9%= Garlic Supplementation at 0.9%

3.2. Effect of garlic supplementation on immunity of broiler chicks

Overall antibody titer against Newcastle disease was non-significant among the experimental groups and control group except GS-0.6% (7.0 HI titer) which was significantly greater ($p \leq 0.05$) than birds in control group (4.3 HI titer). As for as, antibody titer against infectious bursal disease (IBD) was concerned, experimental group (GS-0.9%) shown significantly improved ($p \leq 0.05$) antibody titer in comparison to other experimental groups. Whereas, titer between experimental groups GS-0.3% and GS-0.6% was non-significantly different. Significantly lowest ($p \leq 0.05$) titer was noted for chicks in control group with 31.0 ELISA units as compared to groups supplemented with garlic powder in different proportions as shown in table, 02.

Table 02: Effect of garlic supplementation on immune status of broiler chicks.

Groups	**Antibody titers**	
	Newcastle Disease HI titer	Infectious Bursal Disease ELISA Units
GS-0%	4.3^{a}	31.0^{a}
GS-0.3%	5.7^{ab}	106.0^{b}
GS-0.6%	7.0^{b}	109.4^{b}
GS-0.9%	6.7^{ab}	117.7^{c}

Means with different superscripts are significantly different at α 0.05

GS-0%= Garlic Supplementation at zero level, GS-0.3%= Garlic Supplementation at 0.3%

GS-0.6%= Garlic Supplementation at 0.6%, GS-0.9%= Garlic Supplementation at 0.9%

3.3. Effect of dietary supplementation of garlic powder on serum biochemical parameters during the course of trial

Serum biochemical profile of dietary supplemented broilers is shown in table, 03. Statistical analysis shows that garlic supplementation has significant effect on overall serum biochemical profile of broiler birds. All the variations recorded in the present experiment were found within the level of normal serum profile values for each parameter. A linear significant decrease ($p \leq 0.05$) has been witnessed in the serum triglycerides and total cholesterol levels for experimental groups supplemented with powdered garlic as compared to chicks kept on control diet. On the other hand, a linear significantly increasing ($p \leq 0.05$) trend has been recorded for total serum protein, globulin and albumin.

Table 03: Effect of garlic supplementation on serum biochemical profile of broiler chicks.

Biochemical Parameters	**Control**	**GS-0.3%**	**GS-0.6%**	**GS-0.9%**	P-Value
Total cholesterol (mg/dL)	153.3[a]	144.5[b]	143.9[b]	138.5[c]	<0.001
Triglycerides (mg/dL)	133.4[a]	129.1[b]	127.9[b]	124.7[c]	<0.001
Total serum protein (g/dL)	3.1[a]	3.8[b]	4.1[c]	4.6[d]	<0.001
Globulin (g/dL)	1.2[a]	1.45[b]	1.5[c]	1.6[d]	0.017
Albumin (g/dL)	1.5[a]	1.9[b]	2[b]	2.3[c]	<0.001

Means with different superscripts are significantly different at α 0.05

GS-0%= Garlic Supplementation at zero level, GS-0.3%= Garlic Supplementation at 0.3%

GS-0.6%= Garlic Supplementation at 0.6%, GS-0.9%= Garlic Supplementation at 0.9%

3.4. Economic impact of garlic supplementation in broilers

Effect of dietary supplementation of powdered garlic on economics efficiency of broiler production is presented in table 04. Data shows that supplementation of garlic increased the total cost of broiler production. It was found that garlic supplementation at 0.3%, 0.6% and 0.9% has increased the returns by 3.34%, 4.51% and 4.20% respectively as compared to control group. Highest income/ cost (%) was recorded for experimental group added with 0.6% garlic (52.91%) trailed by experimental group added with 0.9% garlic (50.09%) and then experimental group supplemented with 0.3% garlic (46.83%) as compared to control group (29.10%).

Table 04: Economic impact of garlic supplementation in broiler chicks.

Particulars	**Control**	**GS-0.3%**	**GS-0.6%**	**GS-0.9%**
No of chicks	30	30	30	30
Chicks Price (PKR)	1155	1155	1155	1155
Feed Cost (PKR)	4934.58	4990.44	4997.16	5018.39
Garlic Cost (PKR)	0	22.67	45.40	68.39
Other Costs (PKR)	60	60	60	60
Total Cost (PKR)	6179.58	6258.11	6287.57	6331.79
Returns (PKR)	7977.58	9189.01	9614.51	9503.10
Net Income (PKR)	1798.00	2930.91	3326.94	3171.32
Benefit/ Cost (%)	129.10	146.83	152.91	150.09
Income/ Cost (%)	29.10	46.83	52.91	50.09

GS-0%= Garlic Supplementation at zero level, GS-0.3%= Garlic Supplementation at 0.3%

GS-0.6%= Garlic Supplementation at 0.6%, GS-0.9%= Garlic Supplementation at 0.9%

4. Discussion

The overall outcomes of the present trial are discussed in light of the available literature regarding dietary supplementation of powdered garlic as herbal growth promoting element in poultry birds. Overall feed intake during the course of experimental trial was found significantly similar ($p \geq 0.05$) among the treatment groups which shows that smell and taste of garlic has no adverse consequences on feed intake of broilers. The findings of this study are in line with those of Khaidem and his colleagues 2019 who found non-significant differences for feed intake and feed efficiency while feeding broiler chicks with garlic powder @ 0% (control), 0.25%, 0.50% and 0.75% of their basal diet [16]. The results regarding feed intake of the current study are also in coherence with those of Khan and his colleagues (2017) who testified that garlic extract supplementation in broiler chicks has no significant impact on total feed consumption [17]. The result regarding feed consumption of this study is also supported by Adebiyi and his colleagues (2017) who found that feeding broiler birds with dried raw garlic @ 1%, 2% and 3% has no statistical effect on feed ingestion [18]. Some other researchers including Noman and his colleagues (2015), Varmaghany and his colleagues (2015) and Yalcın and his colleagues (2006) also observed in their studies that dietary addition of garlic has no substantial effect on feed intake of broilers [19-21]. Findings of the current study are also supported by Karangiya and his colleagues (2016) who supplemented broiler chicks with garlic and ginger and found that garlic feeding at 1% has no substantial effect on feed intake in comparison to birds kept on control diet [4]. The outcomes of this experiment are in contrast to those of El-katcha and his colleagues (2016) who reported significantly improved feed intake while supplementing broilers with garlic extract, allicin @ 25, 50, 75 and 100mg/kg of basal diet [22]. They reported an increase of 2.6%, 2.7%, 2.9% and 2.9% in total feed intake of broiler chicks supplemented with allicin @ 25, 50, 75 and 100mg/kg of basal diet respectively. The variation between the results of the two experiments may be attributed to the reason that El-katcha and his colleagues (2016) supplemented the diet with pure allicin extract as compared to whole garlic powder supplementation [22]. Another study who practiced garlic supplementation @0.5%, 1% and 1.5% garlic powder during different growth stages (starter phase, finisher phase and whole raising period) of broiler birds also supports our findings. They found that garlic powder supplementation did not affect feed intake in broiler chicks when offered at starter phase (1-21 days) and throughout the experimental period (1-42 days) however a significant decrease in feed intake was recorded for broilers fed with 1.5% garlic powder in the finisher phase of trail as compared to control birds and inclusion level @ 0.5% [23]. Live weight gain of birds was found non-significantly different ($p \geq 0.05$) during first three weeks of the experimental trial in the current study. Whereas, during 4^{th} week of the trial and overall gain in body weight was found significantly greater for treatment groups as compared to control group with highest weight gain recorded for treatment group G.S-0.6% at the end of the experiment. The results regarding weight gain of the current study are in accordance with the findings of El-katcha and his colleagues (2016) who observed the same trend in body weight gain and concluded that garlic addition (in the form of allicin extract) has no major effect on gain in live body weight during the first three weeks of experimental trial whereas significantly improved weight gain was recorded at the end of the study [22]. The improvement in body weight gain in garlic supplemented groups is attributed to the role of its active ingredients like allicin, oregano sulfur compounds and antibacterial compound dialkyl polysulphie which promotes the performance of intestinal flora by inhibiting pathogenic bacteria and fungi, subsequently results in better utilization of nutrients and their

translation to meat. Additionally, the garlic through its active ingredients boosts the activity of pancreatic enzymes and provide suitable atmosphere for nutrients uptake from digestive tract. The outcomes of the current experiment are also in line with Mahmood and his colleagues (2009) who compared supplementation of 0.5% and 1% kalongi (Nigella sativa) and 0.5% and 1% garlic with control birds and found that 0.5% garlic supplementation in the feed of broiler has significantly enhanced the live body weight gain of broiler chicks [24]. These outcomes are also in accord with those of Karangiya and his colleagues (2016) who observed that garlic and ginger supplementation at 1% level has improved body weight gain significantly [4]. Another study conducted by Al-Rabadi and his colleagues (2020) found that garlic supplementation at 1.5% inclusion rate has significantly increased the live body weight gain in broilers as compared to control group and inclusion rates of 0.5 and 1% also supports our findings. They further concluded that feeding garlic powder for extended period (i.e 1-42d) has markedly improved the weight gain as compared to those birds fed with garlic powder only during the finisher phase of growth [23]. The results of this present trial are in contrast with the outcomes of Khaidem and his colleagues (2019) who investigated that supplementation of garlic has no significant impact on live body weight gain of broilers although higher weight gain was recorded for dietary supplementation of garlic fed at 0.75% level [16]. The difference between the studies may be attributed to various factors including the difference in feeding protocol as they have fed the birds with commercial starter ration from week 0-3 and then commercial finisher ration from week 4-6 whereas in the current experiment the chicks were fed with commercial starter ration throughout the experimental period, season and geographical location of the trials. Feed conversion ratio (FCR) during 1st three weeks of the experimental trial was found non-significantly different whereas significantly higher FCR value was recorded for control group as compared to treatment groups in fourth week and final FCR value. Statistically same FCR was recorded for garlic supplemented groups G.S-0.3%, G.S-0.6% and G.S-0.9% during the course of the trial. The findings of this study are consistent with El-katcha and his colleagues (2016) who reported that supplementation of garlic has significantly improved FCR in broiler chicks in comparison to birds kept on control diet [22]. Some other researchers (El-Gamry and his colleagues 2002; Tollba & Hassan, 2003; Stanaćev and his colleagues 2011; Rehman and his colleagues 2012; Elagib and his colleagues 2013) also testified in their studies that garlic supplementation has significantly improved the feed conversion ratio in broilers [25-29]. Mahmood and his colleagues (2009) also supported our results regarding feed efficiency who found improved FCR for treatment group supplemented @ 0.5% garlic in their ration [24]. The findings of current trial regarding feed efficiency are contrary to the results of Noman and his colleagues (2015) who reported significantly similar FCR valves while feeding broilers with 1% & 2% garlic extract as herbal growth promotes and antibiotics (Ciprofloxacin and Vitamin B-complex) as synthetic growth promoters [19]. Although they recorded better FCR valve for treatment group supplemented with garlic extract @ 1% in comparison to other experimental groups. The variance between the results of these studies may be attributed to the form of garlic being fed to the birds in the two studies as they used garlic extracts, extracted through Soxhlet method instead of powder garlic supplementation. A research trial conducted by Al-Rabadi and his colleagues (2020) also found the same results in terms of feed conversion ratio as noticed during the current study. They found that garlic supplementation did not significantly change the FCR of broiler birds during the starter phase of growth (1-21d) whereas a significantly lowered FCR value was recorded for birds supplemented with 1.5% garlic powder during the finisher phase (22-42d) and all the experimental period (1-42d) as compared to control group [23]. These findings are also in disagreement with those of Karangiya and his colleagues

(2016) who found that supplementation of garlic has no substantial impact on FCR of broilers [4]. Antibody titer against Newcastle disease (ND) was significantly higher for treatment group, GS-0.6% in association to control. Although overall antibody titer against New-castle disease was not significant. Highest ($p \leq 0.05$) antibody titer was recorded for experimental group, GS-0.9% against infectious bursal disease (IBD). In addition to antibacterial and antiviral properties of garlic, it also activates the natural immune system of body against these pathogens. Garlic has immune modulatory compounds which improves the bird's immune response and minimize the age-related decline in the function of body defense mechanism [30]. Garlic supplementation improves the comparative weight of thymus, bursa of fabricius and spleen resulting in improved humoral immune response to viral diseases including ND and IBD [31]. Kyo and his colleagues (2001) conducted an experiment on immune modulatory effects of aged garlic supplements (AGE) in mouse and found that AGE has significantly increased nature killer (NK) cells, splenic cells and release of Cytokines (IL-1 & IL-2) [32]. The findings of Fadlalla and his colleagues (2010) are supporting the results of this study as they investigated that garlic supplementation at 0.3% is significantly improving the cellular immune response of meat type birds by increasing total white blood cells count (TWBC) at the end of the experimental trial [1]. The findings of this study are also supported by Hassan and his colleagues (2013) who recorded improved antibody titer against ND virus in broiler birds supplemented with garlic extract "Allicin oil". They recorded higher antibody titer of 7.7 for garlic treatment group as compared to probiotic (Symopro, Poland) treated group and negative & positive control groups [33]. The findings of this study are also supported by those of Fallah, (2014) who reported higher antibody titers against ND and influenza in broilers supplemented with garlic and garlic-aloe Vera mix in different proportions [34]. Serum biochemical profile reveals that addition of garlic has significant ($p \leq 0.05$) effect on overall serum biochemical profile of broilers. A linear decreasing trend was recorded for total cholesterol and triglycerides. On the other hand, a linear increase was observed for total serum protein, globulin and albumin. The outcomes of this experiment are in harmony with those of El-katcha and his colleagues (2016) who recorded significantly reduced blood serum triglycerides & total cholesterol level and significantly increased blood serum total protein and albumen after supplementation of broilers with garlic extract (allicin) [22]. Their findings regarding serum globulin are in contrast to this study as they found no significant difference in birds offered with allicin in association to control group. The hypo-cholesterolemic effects of garlic extracts may be attributed to inhibition of the enzymes activity involved in the formation of lipids and cholesterol [27]. Some other scientists (Qureshi and his colleagues1983; Konjufca and his colleagues 1997; Chowdhury and his colleagues 2002; Rehman and Munir, 2015) described that garlic supplementation reduced the activities of fatty acid synthase, 3-hydroxy-3-methyl-glutaryl-CoA (HMG-CoA) reductase, cholesterol 7α- hydroxylase and glucose-6 phosphate dehydrogenase significantly [30, 35-37]. The findings regarding reduction in blood cholesterol level are also supported by Canogullari and his colleagues 2010 who observed substantial reduction in cholesterol level inside the plasma of laying quails fed with powdered garlic [13]. The findings of the current trial are in contrast to those of Amouzmehr and his colleagues (2012) who investigated that garlic extracts supplementation has no significant impact on triglycerides, blood cholesterol and high-density lipids [8]. The variance between the findings of these studies may be credited to the reason that they have supplemented the chicks with garlic extract instead of raw garlic powder in the current study. Garlic supplementation has increased the economic efficiency of broiler production in terms of net return/ income. The improvement in economic efficiency may be attributed to the higher weight gain and better feed utilization by the experimental

birds as compared to birds kept on basal diet. The judgments of the current study are supported by Oleforuh-Okoleh and his colleagues (2014) and El-katcha and his colleagues (2016) who found highest returns in terms of economics from broilers fed with powdered garlic in comparison to birds kept on control diet [22, 38]. The findings of current experimental trial are contrary to the reports of Karangiya and his colleagues (2016) who found non-substantial effect on return over feed cost (ROFC) for garlic supplementation in broilers whereas significantly improved ROFC was recorded for ginger supplementation in their study [4]. The differences amongst the findings of this study and some other investigators may be credited to variation in overall composition of diet, inclusion level of garlic and/or its extracts, form of garlic supplementation and breed/ strain of birds used. The potential limitations of this study may include variable outcome with respect to geographical location, seasonal variations and breed/type of birds.

5. Conclusions and Recommendations

In light of the findings of this trial, it is determined that addition of garlic in broiler's diet can be effectively practiced and antibiotic growth promoters can be easily replaced with garlic. Garlic supplementation has significantly improved the final body weight, FCR and immunity of birds. Garlic supplementation @ 0.6% in basal diet is recommended for better and economic production in meat type birds.

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6. Conflict of Interest

The authors declare no conflict of interest.

References

[1] I. Fadlalla, B. Mohammed, and A. Bakhiet, "Effect of feeding garlic on the performance and immunity of broilers," Asian Journal of Poultry Science, vol. 4, pp. 182-189, 2010.

[2] M. Ali, N. Chand, R. U. Khan, S. Naz, and S. Gul, "Anticoccidial effect of garlic (Allium sativum) and ginger (Zingiber officinale) against experimentally induced coccidiosis in broiler chickens," Journal of applied animal research, vol. 47, pp. 79-84, 2019.

[3] E. Rahmatnejad, H. Roshanfekr, O. Ashayerizadeh, M. Mamooee, and A. Ashayerizadeh, "Evaluation the effect of several non-antibiotic additives on growth performance of broiler chickens," Journal of Animal and Veterinary Advances, vol. 8, pp. 1757-1760, 2009.

[4] V. Karangiya, H. Savsani, S. S. Patil, D. Garg, K. Murthy, N. Ribadiya, et al., "Effect of dietary supplementation of garlic, ginger and their combination on feed intake, growth performance and

economics in commercial broilers," Veterinary world, vol. 9, p. 245, 2016.

[5] S. B. Aji, K. Ignatius, A. Ado, J. B. Nuhu, A. Abdulkarim, U. Aliyu, et al., "Effects of feeding onion (Allium cepa) and garlic (Allium sativum) on some performance characteristics of broiler chickens," Res. J. Poult. Sci, vol. 4, pp. 22-27, 2011.

[6] M. Borazjanizadeh, M. Eslami, M. Bojarpour, M. Chaji, and J. Fayazi, "The Effect of Clove and Oregano on Economic Value of Broiler," Journal of Animal and Veterinary Advances, vol. 10, pp. 169-173, 2011.

[7] R. Z. Abbas, Z. Iqbal, M. S. Akhtar, M. N. Khan, A. Jabbar, and Z.-u.-D. Sandhu, "Anticoccidial screening of Azadirachta indica (Neem) in broilers," Pharmacologyonline, vol. 3, pp. 365-371, 2006.

[8] A. Amouzmehr, B. Dastar, J. G. Nejad, K.-I. Sung, J. Lohakare, and F. Forghani, "Effects of garlic and thyme extracts on growth performance and carcass characteristics of broiler chicks," Journal of Animal Science and Technology, vol. 54, pp. 185-190, 2012.

[9] A. Tekeli, H. Kutlu, L. Celik, I. Var, E. Yurdakul, and A. Avcy, "The use of Propolis as an alternative to antibiotic growth promoters in broiler diets," in Proceedings of 23th Worlds Poultry Congress, 2008, pp. 482-482.

[10] G. Fenwick and A. Hanley, "The genus Allium. II," CRC Critical reviews in food science and nutrition, vol. 22, pp. 199-271, 1985.

[11] M. Adibmoradi, B. Navidshad, J. Seifdavati, and M. Royan, "Effect of dietary garlic meal on histological structure of small intestine in broiler chickens," The Journal of Poultry Science, vol. 43, pp. 378-383, 2006.

[12] R. Khan, Z. Nikousefat, V. Tufarelli, S. Naz, M. Javdani, and V. Laudadio, "Garlic (Allium sativum) supplementation in poultry diets: Effect on production and physiology," World's Poultry Science Journal, vol. 68, pp. 417-424, 2012.

[13] S. Canogullari, M. Baylan, Z. Erdogan, V. Duzguner, and A. Kucukgul, "The effects of dietary garlic powder on performance, egg yolk and serum cholesterol concentrations in laying quails," Czech Journal of Animal Science, vol. 55, pp. 286-293, 2010.

[14] J. Gardzielewska, K. Pudyszak, T. Majewska, M. Jakubowska, and J. Pomianowski, "Effect of plant-supplemented feeding on fresh and frozen storage quality of broiler chicken meat," J. Polish. Agric. Univ, vol. 6, 2003.

[15] D. B. Duncan, "Multiple range and multiple F tests," Biometrics, vol. 11, pp. 1-42, 1955.

[16] A. Khaidem, R. Zuyie, N. Haque, and V. Vidyarthi, "Effect of garlic supplementation on

performance.carcass traits and blood profile of broiler chicken," International Journal of Bio-resource and Stress Management, vol. 10, pp. 292-297, 2019.

[17] M. S. I. Khan, M. S. Prodhan, M. S. Islam, M. N. Hasan, and M. S. Islam, "Effect of garlic extract on growth performances and hematological parameters of broilers," Asian Journal of Medical and Biological Research, vol. 3, pp. 317-322, 2017.

[18] F. Adebiyi, A. Ologhobo, and I. Adejumo, "Efficacy of Allium sativum as growth promoter, immune booster and cholesterollowering agent on broiler chickens," Asian Journal of Animal Science, vol. 11, pp. 202-213, 2017.

[19] Z. Noman, M. Hasan, S. Talukder, Y. Sarker, T. Paul, and M. Sikder, "Effects of garlic extract on growth, carcass characteristics and haematological parameters in broilers," Bangladesh Veterinarian, vol. 32, pp. 1-6, 2015.

[20] S. Varmaghany, M. A. K. Torshizi, S. Rahimi, H. Lotfollahian, and M. Hassanzadeh, "The effects of increasing levels of dietary garlic bulb on growth performance, systolic blood pressure, hematology, and ascites syndrome in broiler chickens," Poultry science, vol. 94, pp. 1812-1820, 2015.

[21] S. Yalcın, E. E. Onbaşılar, Z. Reisli, and S. Yalcın, "Effect of garlic powder on the performance, egg traits and blood parameters of laying hens," Journal of the Science of Food and Agriculture, vol. 86, pp. 1336-1339, 2006.

[22] M. I. El-katcha, M. A. Soltan, M. M. Sharaf, and A. Hasen, "Growth performance, immune response, blood serum parameters, nutrient digestibility and carcass traits of broiler chicken as affected by dietary supplementation of garlic extract (Allicin)," Alexandria Journal of Veterinary Sciences, vol. 49, pp. 50-64, 2016.

[23] N. Al-Rabadi, R. Haddad, M. A. Al-Hijazeen, M. Massoh, J. M. Alqudah, A. G. Jiries, et al., "Effect of Garlic powder Supplementation level at different growth stages on Broiler performance," Bull. Env. Pharmacol. Life Sci, vol. 9, pp. 67-76, 2020.

[24] S. Mahmood, M. Mushtaq-Ul-Hassan, M. Alam, and F. Ahmad, "Comparative efficacy of Nigella sativa and Allium sativum as growth promoters in broilers," International Journal of Agriculture and Biology, vol. 11, pp. 775-778, 2009.

[25] A. El-Ghammry, G. El-Mallah, and A. El-Yamny, "The effect of incorporation yeast culture, Nigella sativa seeds and fresh garlic in broiler diets on their performance," Egyptian Poultry Science, vol. 22, pp. 445-459, 2002.

[26] A. Tolba and M. Hassan, "Using some natural additives to improve physiological and productive performance of broiler chicks under high temperature condition," 2003.

[27] V. Stanaćev, D. Glamočić, N. Milošević, N. Puvača, V. Stanaćev, and N. Plavša, "Effect of garlic (Allium sativum L.) in fattening chicks nutrition," African Journal of Agricultural Research, vol. 6, pp. 943-948, 2011.

[28] Z. Rehman, S. Khan, N. Chand, A. Tanweer, A. Sultan, A. Akhtar, et al., "Effect of water based mixture infusion of Allium sativum and Withania somnifera on performance of broiler chicks," Pakistan Journal of Science, vol. 64, p. 180, 2012.

[29] H. Elagib, W. El-Amin, K. Elamin, and H. Malik, "Effect of Dietary Garlic (Allium sativum) Supplementation as Feed Additive on Broiler Performance and Blood Profile,"

[30] M. T. Munir, "Effect of garlic on the health and performance of broilers," Veterinaria, vol. 3, pp. 32-39, 2015.

[31] H. Hanieh, K. Narabara, M. Piao, C. Gerile, A. Abe, and Y. Kondo, "Modulatory effects of two levels of dietary Alliums on immune response and certain immunological variables, following immunization, in White Leghorn chickens," Animal Science Journal, vol. 81, pp. 673-680, 2010.

[32] E. Kyo, N. Uda, S. Kasuga, and Y. Itakura, "Immunomodulatory effects of aged garlic extract," The Journal of nutrition, vol. 131, pp. 1075S-1079S, 2001.

[33] E. R. Hassan, K. M. ELbayoumi, H. M. Mekky, D. Sedeek, N. S. Rabie, and Z. Girh, "Comparative study on effect of garlic extract and probiotic on the productivity and immune response of broiler chickens to live newcastle disease vaccine," Global Vet, vol. 11, pp. 630-633, 2013.

[34] R. Fallah, "Effects of supplementing Aloe vera gel and garlic powder on blood biochemical parameters and immune response of broiler," Journal of Medicinal Plants Research, vol. 8, pp. 1035-1039, 2014.

[35] A. A. Qureshi, N. Abuirmeileh, Z. Z. Din, C. E. Elson, and W. C. Burger, "Inhibition of cholesterol and fatty acid biosynthesis in liver enzymes and chicken hepatocytes by polar fractions of garlic," Lipids, vol. 18, pp. 343-348, 1983.

[36] V. Konjufca, G. Pesti, and R. Bakalli, "Modulation of cholesterol levels in broiler meat by dietary garlic and copper," Poultry science, vol. 76, pp. 1264-1271, 1997.

[37] S. Chowdhury, S. Chowdhury, and T. Smith, "Effects of dietary garlic on cholesterol metabolism in laying hens," Poultry science, vol. 81, pp. 1856-1862, 2002.

[38] V. Oleforuh-Okoleh, G. Chukwu, and A. Adeolu, "Effect of ground ginger and garlic on the growth performance, carcass quality and economics of production of broiler chickens," Glob. J. Biosci. Biotechnol, vol. 3, pp. 225-229, 2014.