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# GARLIC AS A NATURAL ANTICOCCIDIAL AND ANTIOXIDANT: EFFECTS ON PERFORMANCE, GUT HEALTH, AND IMMUNITY IN BROILERS

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## ABSTRACT

Coccidiosis caused by *Eimeria* spp. causes significant economic losses in poultry. This study evaluated the anticoccidial and antioxidant effects of dietary garlic in broilers challenged with coccidiosis, as well as its impacts on gut health, performance, blood parameters, and immunity. A total of 375 Ross 308 broilers were divided into five groups: two received garlic treatments Tg1 (liquid garlic with 7% allicin) and Tg2 (garlic powder); one received a synthetic anticoccidial (T+ve: sulphonamide + diaveridine HCl); and two served as controls (T-ve1: infected, T-ve2: non-infected). Birds were infected on day 14; treatments began on day 12, garlic supplementation significantly reduced fecal oocyst shedding ($P<0.05$), lesion scores, and oocyst index compared to infected controls, with effects comparable to synthetic anticoccidials. Garlic-treated groups showed an improved feed conversion ratio (FCR) and higher total antioxidant capacity ($P<0.05$), along with lower malondialdehyde levels, indicating reduced oxidative stress. Blood levels of total protein, albumin, phosphorus, cholesterol, glucose, and uric acid did not differ significantly ($P>0.05$). Histopathology revealed improved gut integrity with longer villi and less epithelial necrosis in the garlic groups. Antibody titers against Newcastle disease and infectious bronchitis viruses were unchanged. These results indicate that garlic, especially in liquid form, is a promising natural alternative to synthetic anticoccidials, enhancing gut health, antioxidant defense, and metabolic status in broilers challenged with coccidiosis without fostering drug resistance.

***Keywords*:** Antioxidant, Broiler chickens, Coccidiosis, Garlic, Gut health.

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## 1. INTRODUCTION

Coccidiosis is an economically significant disease in the poultry industry, leading to substantial production losses, morbidity, and mortality rates that can exceed 50% (Chapman et al., 2010). The disease is caused by protozoan parasites of the genus *Eimeria*, with seven species being particularly impactful in poultry (Blake & Tomley, 2014; Chapman, 2014). In commercial operations, prevention has historically depended on the use of coccidiostats and coccidiocidals. However, the prolonged and often misuse of these drugs has led to widespread resistance in *Eimeria* parasites (Chapman, 2014), necessitating the exploration of alternative control strategies.

Garlic (Allium sativum) and its primary bioactive component, allicin, are known for their antimicrobial and antioxidant properties (Hassan et al., 2024; Eltanahy et al., 2025). While dietary garlic powder has shown promise in improving broiler performance and immunity (Abd El-Ghany, 2024; Zhang et al., 2024), critical gaps hinder its standardized application for coccidiosis control. Firstly, direct comparisons between well-characterized garlic formulations are scarce. Specifically, there is a lack of controlled studies comparing conventional garlic powder with a liquid garlic extract containing standardized, quantified allicin under a controlled Eimeria challenge. This gap is significant because garlic's efficacy is directly linked to its allicin yield, which is highly variable in raw powder but can be stabilized in processed extracts. Secondly, the existing literature lacks dose standardization based on bioactive compound concentration (e.g., allicin), making it difficult to determine effective and reproducible doses. Finally, while the general benefits of garlic are recognized, its mode of action against coccidiosis remains incompletely elucidated. There is a pressing need for studies that concurrently evaluate anticoccidial efficacy (oocyst shedding, lesion scores) alongside key physiological parameters, such as gut morphology and systemic oxidative stress biomarkers, to provide a holistic understanding of its protective effects.

Therefore, we hypothesized that dietary supplementation with garlic would mitigate coccidiosis in broilers, and that a liquid garlic extract, standardized to a specific allicin content, would have superior efficacy compared to raw garlic powder due to its higher and more reliable bioavailability. This study was designed to provide a comprehensive evaluation by directly comparing these two forms under a controlled Eimeria challenge. We specifically investigated their dose-dependent effects based on allicin equivalence, while simultaneously measuring

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a suite of responses: from zootechnical performance and direct anticoccidial metrics (oocyst output, lesion scores) to intestinal histology and systemic oxidative stress markers, thereby linking efficacy to physiological mode of action.

## 2. MATERIALS AND METHODS

### 2.1. Study Location

This research was conducted at the Poultry Production Unit of the Jordan University Station for Dry Land Research at Al-Muwaqqar, located 45 km southeast of Amman, Jordan. The facility consisted of a closed house with 10 rooms, each divided into 3 chambers. Each chamber was equipped with heaters, drinkers, feed troughs, and a controlled lighting system.

### 2.2. Experimental Birds and Management

A total of 375 day-old Ross 308 broiler chicks were obtained from a local commercial hatchery. After a 10-day acclimatization period, the chicks were randomly distributed into experimental groups on day 12. All chicks had a similar initial body weight (48±0.05 g). Birds were reared on deep wood shavings litter in floor pens, with ad libitum access to feed and water throughout the study. The birds were managed according to standard commercial practices and Ross 308 breed guidelines.

The birds received a broiler starter diet until day 14, followed by a finisher diet until the end of the experiment (day 35). The composition of the experimental diets is presented in Table 1. The room temperature was maintained at 32°C during the first week and gradually reduced by 0.5°C weekly thereafter. A 24-hour lighting schedule was maintained throughout the trial. All birds were vaccinated against infectious bronchitis (day 1) and Newcastle disease (day 7) following standard protocols (Hayajneh et al., 2023).

**Table 1:** Composition of broiler basal feed (g/kg)

| Ingredients | Starter (0-21 d) | Finisher (22-35 d) |
|---|---|---|
| Maize | 540.0 | 710.0 |
| Soybean meal (480g/kg CP) | 360 | 250.0 |
| Dicalcium phosphate | 20 | 20.0 |
| Soybean oil | 13 | 13.0 |
| Fish meal | 60 | 0 |
| DL-Methionine | 1.5 | 0.5 |
| Vitamin-mineral premix[a,b] | 3.5 | 3.5 |
| Sodium chloride | 2.0 | 3.0 |
| Chemical composition (g/kg diet as fed basis) | | |
| Men (MJ/kg) | 12.6 | 13.0 |
| Crude protein | 235.0 | 182.0 |
| Calcium | 12.3 | 8.0 |
| Total Phosphorus | 6.5 | 5.1 |
| Lysine | 17.0 | 10.0 |
| Methionine | 9.0 | 8.0 |

[A]vitamin premix provided per kilogram of diet: Vitamin A=0.5760; Vitamin K=?IU; Vitamin B5=19.4532mg; Tocopherol=4.6799mg; Vitamin B1=3.5016mg; Vitamin B2=1.6994mg; Vitamin B6=6.4911mg; Vitamin B12=16mg; Biotin=0.1382mg; Folic Acid=1.2692mg; Pantothenic=7.8104mg; Vitamin K3=0.9071mg; [b]trace mineral premix per kg diet were: Iron= 62.0061mg; Zinc=43.065mg; Copper=6.855mg; Iodine=0.0589mg; Selenium=1.3466mg. Soybean concentrate and mono-calcium phosphate were also provided.

### 2.3. Experimental Design

On day 12, chicks were weighed and randomly assigned to five dietary treatments in a Randomized Complete Block Design (RCBD), with body weight as the blocking factor. Each treatment consisted of three replicates (pens) containing 25 birds each (75 birds per treatment) (Table 2).

### 2.4. Drugs and Administration

The liquid garlic extract (Rhodes feed additives, Spain) was a commercially standardized product guaranteed by the manufacturer to contain 7% allicin (equivalent to 70,000 ppm). The raw garlic powder was sourced from the local market. To ensure validity and reproducibility, a representative sample of the garlic powder batch used in the experiment was chemically profiled. The analysis was performed using High-Performance Liquid Chromatography (HPLC) according to Lanzotti et al. (2014). The powder was found to contain 0.25% allicin (equivalent to 2,500 ppm), 0.8% alliin, and 1.5% total sulfur compounds. This characterization confirms the bioactivity of the powder and allows for accurate dose comparison. The final dietary concentration in the Tg2 group (3g garlic powder/kg feed) provided a calculated allicin equivalent of 75 ppm in the final diet.

**Table 2:** Group arrangement in the experiment

| Group | Drug Used | Dose | Coccidiosis Introduced |
|---|---|---|---|
| $T_{g1}$ | Garlic liquid | 1ml/L water,7% Alicin garlic from Rhoodes feed additives (Spain) | Yes |
| $T_{g2}$ | Garlic powder | 3gm/kg feed, powder purchased from local market | Yes |
| $T_{+ve}$ | Sulphadimidine 320mg and diaverdine HCL 10mg | 100mg/200l drinking water for three days, followed by plain water /2days, then the medication was added in water 100mg/200l water/2days | Yes |
| $T_{-ve1}$ | Infected medicated with bentonite 1.5mg/kg | 1.5mg/kg, bentonite | No |
| $T_{-ve2}$ | None infected none medicated | None | No |

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On day 12, the drugs were given to the birds daily. Sulphadimidine 320 mg and diaverdine HCL 10mg (Avico, Amman, Jordan) was administered to birds in the T+ve group at a concentration of (100mg/200L drinking water for three days, followed by plain water /2 days, then the medication was added in water 100mg/200L water/2 days). Liquid garlic from Rhodes feed additives (allicin 7 %, Spain) was given to group Tg1 at a concentration of 1 ml/l water/ 7 days, and garlic powder (from local market) 3g/kg/7 days feed in group Tg2. Nothing was added to T-ve1 and T-ve2 (Table 2).

Dietary treatments were administered from day 12 onwards:

- **T+ve**: Received sulphadimidine (320 mg) and diaverdine HCL (10mg) (Avico, Amman, Jordan) at 100mg/200L drinking water for three days, followed by plain water for two days, then medication resumed for two days.
- **Tg1**: Received liquid garlic extract at 1 ml/L drinking water for 7 consecutive days.
- **Tg2**: Received garlic powder at 3g/kg feed for 7 consecutive days.
- **T-ve1 and T-ve2**: Received basal diet and water without additives.

### 2.5. Coccidiosis Induction

To establish coccidiosis, birds were orally challenged on day 14 with a 10x dose of a commercial live oocyst vaccine (Coccivac®-B, Merck Animal Health), following the experimental model described by Bozkurt et al. (2016). This model is recognized for producing a consistent infection suitable for evaluating feed additives

### 2.6. Performance Parameters

Feed intake, body weight, average feed intake, and feed conversion ratio (FCR) were calculated on days 21, 28, and 35. Also, oocysts per gram of feces, lesion score, and oocyst scoring were recorded on days 21, 28, and 35. Health aspects and mortality were monitored daily. Meat quality was determined using the methods described by Hossain et al. (2014).

### 2.7. Lesion Scoring and Oocyst Index

On days 7, 14, and 21 post-inoculation (experimental days 21, 28 and 35), one bird per replicate (three birds per treatment per time point) was randomly selected by a blinded technician using a numbered list of all birds in each pen. Selected birds were humanely euthanized for concurrent coccidial lesion scoring and oocyst counting. Lesion scores were recorded using a 0-4 scale (Johnson and Reid, 1970), while oocyst counts were determined using a 0-5 index (Arabkhazaeli et al., 2013).

### 2.8. Histopathological Examination

Intestinal tissue samples (duodenum, jejunum, and cecum) were collected from euthanized birds immediately after sacrifice. Tissues were preserved in 10% neutral buffered formalin, processed through routine dehydration and embedding in paraffin wax, sectioned at 4-5µm thickness, and stained with Hematoxylin and Eosin (H&E) for microscopic examination (Li et al., 2023).

### 2.9. Evaluation of Sensitivity or Resistance

On day 12, 17 chicks were randomly selected from each group, weighed, and then reweighed on day 21; the difference in body weight gain between days 12 and 21 was calculated. Five chicks from each group were sacrificed on day 21, and the intestinal lesion score was recorded according to the method described by Dakroury et al. (2016). The gross lesion scores (GLS) were assessed on a scale of 0 (no gross lesion) to 4 (most severe lesion). After microscopic examination of intestinal scrapings taken from sacrificed birds, the oocyst index was determined (0-5) according to Arabkhazaeli et al. (2013). The sensitivity of drugs was determined using the global index (GI), and the GI was calculated using the formula described by Arabkhazaeli et al. (2013). Efficacy status was calculated as a percentage of the Gastrointestinal tract for the T-ve2 group.

### 2.10. Measurements

Magnesium, creatinine, and uric acid were measured using ELISA kits from Biolab, Jordan. Albumin, cholesterol, magnesium, total protein, bilirubin and phosphorus were measured using an ELISA kit from Biomed, MDSS Gmbh, Germany. Glucose was measured using an ELISA kit from Atlas Medical Jordan. Uric acid was measured using an ELISA kit from ARCOMEX Jordan. Zinc was measured using a spectrophotometry kit from Ita, Italy. Total antioxidant capacity and Malondialdehyde were measured using Assay Kits from Creative Proteomics, USA. To measure the titter of Newcastle and infectious bursal disease antibodies in the serum, a commercial ELISA kit from BioChek Immunoassays (BioCheck, Reeuwijk, Netherlands) was used according to the manufacturer's guidelines. The cut-off used was <0.35. The antibody measurement tests were performed in Feedco Labs, Jordan.

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### 2.11. Meat Quality Evaluation

On day 35, following commercial processing simulation, meat quality parameters were assessed on Pectoralis major samples using established methods (Hossain et al., 2014):

- Water-holding capacity: Determined as cooking loss percentage
- Tenderness: Measured as shear force using a texture analyzer
- Color: Instrumental color values (L, *a*, b*) measured using a chroma meter

### 2.12. Statistical Analysis

All data were analyzed using SPSS software (Version 20.0; IBM Corp., Armonk, NY, USA). The effects of dietary treatments on all measured parameters were analyzed using a General Linear Model (GLM) for multivariate analysis. The treatment group was included as a fixed factor. When a significant overall effect was found ($P \leq 0.05$), Tukey's post-hoc test was applied to separate the means between individual treatment groups. Results are presented as mean±SEM.

## 3. RESULTS

### 3.1. Anticoccidial Efficacy, Antioxidant Status and Immunity

Dietary supplementation with garlic significantly influenced the birds' response to the coccidial challenge. Both garlic-treated groups (Tg1 and Tg2) exhibited a substantial reduction in fecal oocyst shedding, lesion scores, and oocyst index compared to the icompared to the infected untreated control (T-ve1) ($P<0.05$) (Table 3, Fig. 4a, Fig. 6, Fig. 8). Critically, the anticoccidial performance of both Tg1 and Tg2 was statistically non-inferior to the synthetic drug group (T+ve) for all key parameters ($P>0.05$), while being significantly superior to T-ve1 ($P<0.05$) (Table 3, Fig. 4a, Fig. 6, Table 7).

**Table 3:** Comparative values of FCR, lesion score, oocyst index, mortality percentage, global index, and efficacy status

| Group | FCR (g/g) | Lesion score | Oocyte index | Mortality | GI % | The global index of NNC% | Efficacy status |
|---|---|---|---|---|---|---|---|
| TG1 | 1.24 | 1 | 1 | 1 | ≥90% | 66.3 | 1 |
| TG2 | 1.13 | 1 | 2 | 2 | ≥90% | 69.5 | 1 |
| T+ve | 1.48 | 3 | 3 | | Limited efficacy | 77 | 3 |
| TNNC (T-ve2) | 1.35 | 4 | 5 | | | | |
| TINC (T-ve1) | 1.39 | 4 | 5 | | | | |

Tch1, 2= Charcoal-medicated group; NNC=Noninfected, nonmedicated control (T-ve2). INC=Infected nonmedicated controls (T-ve1); Global index (GI) = %WGNNC − [(FM− FNNC) × 10] − (OIM − OIINC) − [(LSM − LSINC) × 2] − (%mortality/2), where WG is weight gain, F is the FCR, OI is the oocyst index, LS is the lesion score, M is the medicated group, NNC is the noninfected, nonmedicated control group, and INC is the infected nonmedicated control group. Efficacy status was calculated as a percentage of the GI for the NNC. The following 5 categories were used for testing resistance to anticoccidials: 1) very good efficacy, ≥90% GINNC; 2) good efficacy, 80 to 89% GINNC; 3) limited efficacy, 70 to 79% GINNC; 4) partially resistant, 50 to 69% GINNC; and 5) resistant.

The antioxidant capacity of the birds was also significantly enhanced by garlic supplementation. The highest total antioxidant capacity (TAC) and the lowest malondialdehyde (MDA) concentrations were observed in groups Tg1 and Tg2 (Fig. 1 & 2), indicating a reduction in oxidative stress.

A significant difference in spleen weight was noted between groups (Fig. 3), while liver and bursa weights were not significantly affected by dietary treatments (Table 5). The heaviest spleens observed in Tg2 and the lightest in Tg1 and T+ve during weeks 1 and 3. In contrast, no significant differences were found in antibody titers against Newcastle disease or infectious bronchitis viruses among the treatment groups Fig. 4b.

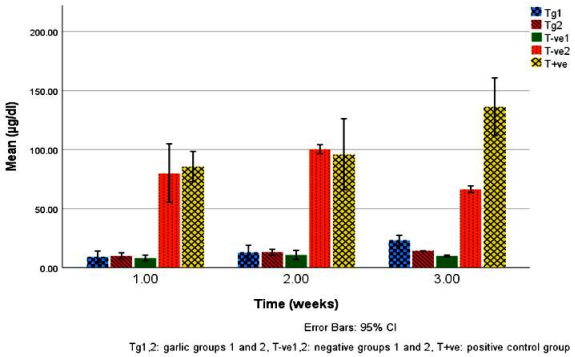


**Fig. 1:** Total antioxidant capacity (TAC) in serum of broilers from different treatment groups.

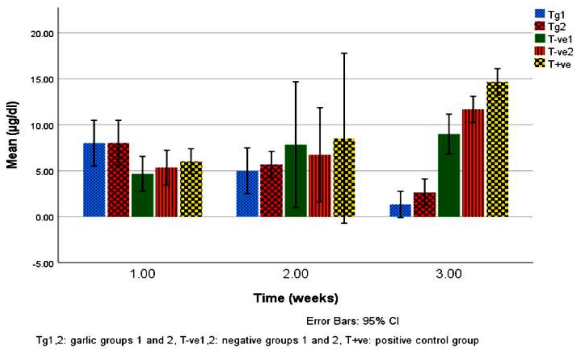


**Fig. 2:** Malondialdehyde (MDA) concentrations in serum of broilers from different treatment groups.

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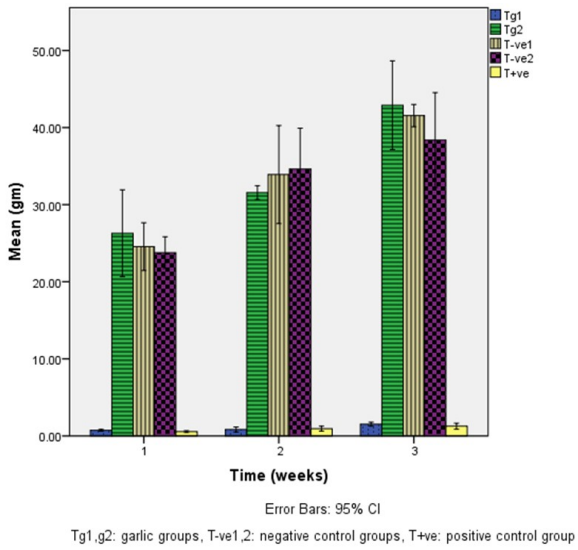


**Fig. 3:** Spleen weight in the different groups

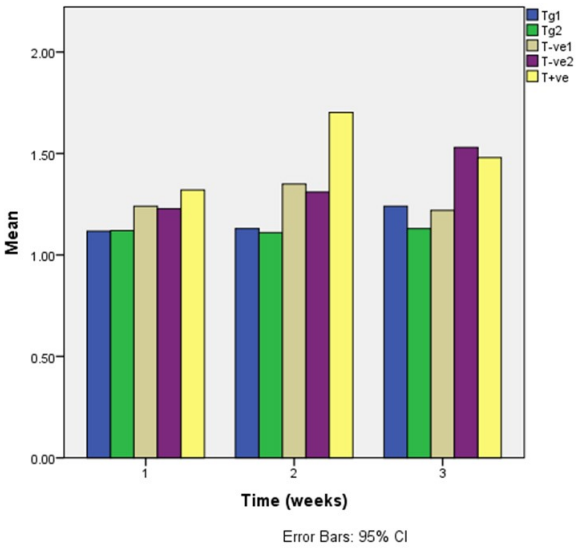


**Fig. 5:** Feed conversion ratio in the different groups.

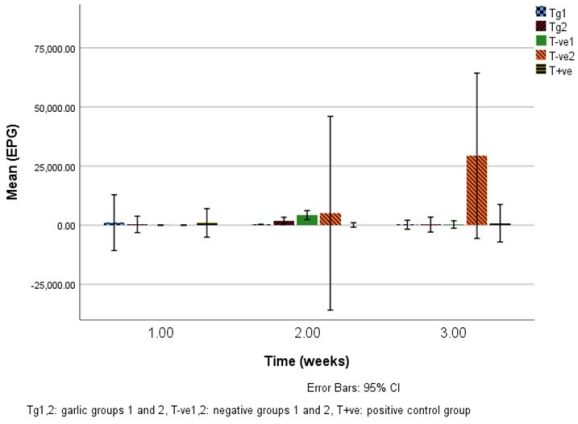


**Fig. 4:** Fecal oocyst shedding count across treatment groups over time.

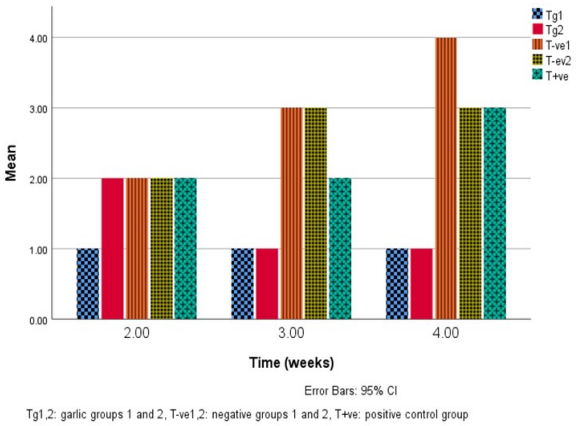


**Fig. 6:** Lesion score

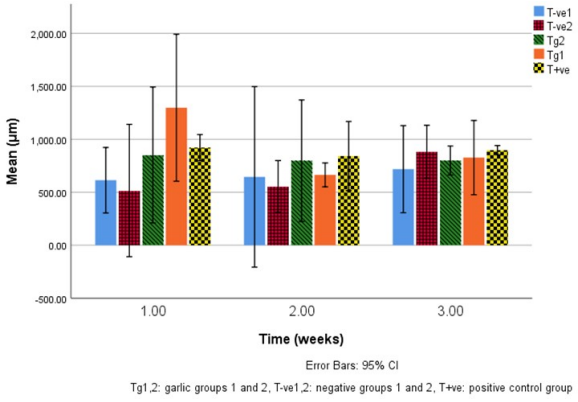


**Fig. 7:** Villi length in the different groups.

### 3.2. Villi Morphology and Histopathology

Garlic supplementation positively affected intestinal morphology. A significant increase in villi length ($P<0.05$) was observed in groups Tg1 and Tg2 during weeks 2 and 3 compared to other groups (Fig. 7; Table 8). However, no significant differences were found in villi width, crypt depth, or villi surface area (Table 8). Histopathological examination revealed clear benefits in gut integrity for the garlic-treated birds. Epithelial necrosis and heavy infection with various parasite developmental stages were prominent in the T-ve1 and T-ve2 groups. In contrast, the Tg1 and T+ve groups showed normal epithelium and markedly reduced parasitic infection (Fig. 9).

### 3.3. Growth Performance and Meat Quality

A significant difference in the feed conversion ratio (FCR) was observed among the groups (Table 7, Fig. 5). The lowest (i.e., best) FCR values were recorded in the Tg1 and Tg2 groups in week 3, while the highest values were seen in T-ve1 and T+ve. No significant

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differences were detected in overall feed intake or weight gain between the groups. The inclusion of garlic significantly affected several meat quality parameters (Table 6). Significant differences were observed in muscle weight, fillet weight, color coordinates (L, *b*), cooking loss, water-holding capacity, and shear force between the treatment groups.

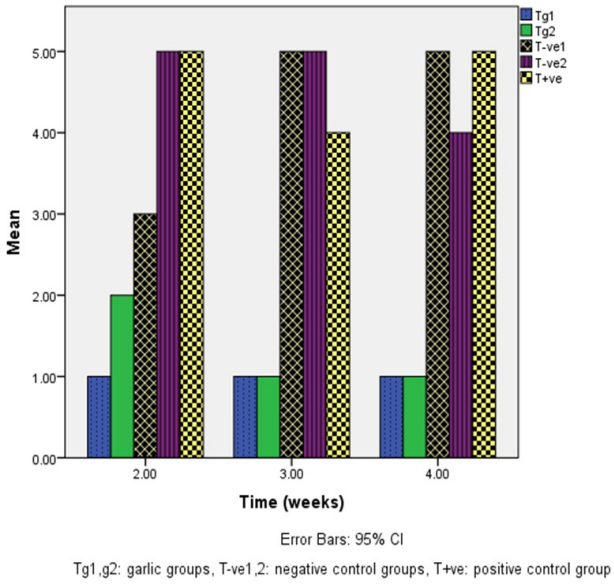


**Fig. 8:** Oocyte index in the different groups.

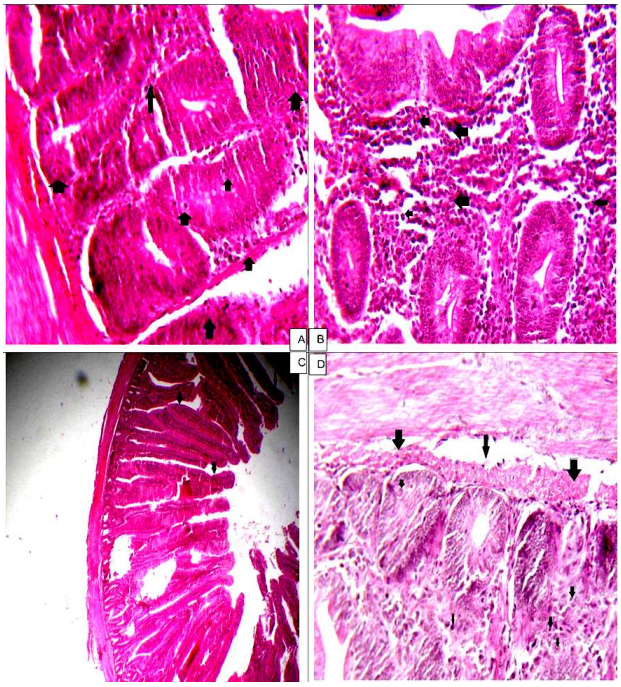


**Fig. 9:** Histopathology of the intestine in different groups, showing different stages of Eimeria in the intestine (A, B: T-ve1, and D: T-ve2 in) and changes in the columnar mucosal epithelium (C, group T-ve2) at 40X.

The significantly lower malondialdehyde (MDA) levels in garlic-supplemented groups ($P<0.05$) indicate reduced lipid peroxidation in breast and thigh meat. This finding is consistent with Zhang et al. (2023), who reported that allicin enhances antioxidant enzyme activity (SOD, CAT) in muscle tissue. Improved oxidative stability is crucial for extended shelf life and better nutritional retention.

Recent studies (Karre et al., 2013; Rusli et al., 2022) confirm that dietary garlic at 7% allicin (as used in our Tg1 group) can delay meat spoilage by 15–20% compared to controls, making it a viable alternative to synthetic preservatives.

While our study did not conduct formal sensory panel tests, the numerical improvements in meat color and water-holding capacity (WHC) in garlic-fed birds suggest better consumer appeal. Liao et al. (2022) found that garlic straw powder improved tenderness, juiciness and color stability.

These effects may stem from garlic's antimicrobial properties, reducing spoilage bacteria (Hassan et al., 2024) and its role in modulating muscle fiber structure (Alagbe et al., 2023).

The inclusion of garlic in broiler diets led to notable improvements in meat quality parameters, consistent with recent research on phytogenic feed additives in poultry production. Our findings contribute to the growing body of evidence supporting natural alternatives to synthetic growth promoters and anticoccidials, particularly in terms of meat safety, oxidative stability and sensory attributes.

### 3.4. Blood Parameters

The metabolic profile of the birds remained largely stable across treatments. No significant differences were observed in the blood concentrations of cholesterol, glucose, uric acid, creatinine, total protein, albumin, phosphorus, zinc, or magnesium (Table 4a, b).

## 4. DISCUSSION

The findings of this study demonstrate that dietary garlic is an effective natural agent for mitigating coccidiosis in broilers, with efficacy comparable to synthetic anticoccidials. Our results strongly support the hypothesis that garlic, particularly in its standardized liquid form (Tg1), can serve as a viable alternative, addressing key industry concerns such as drug resistance and oxidative stress.

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**Table 4a:** Blood parameters (minerals and proteins) in the different groups

| Dependent Variable | (I) Group | (J) Group | Mean Difference (I-J) | SEM | P value. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound |
| Albumin | Tg1 | T-ve1 | -0.05 | 0.05 | 0.34 | -0.15 | 0.05 |
| | | Tg2 | -0.03 | 0.05 | 0.55 | -0.13 | 0.07 |
| | | T-v2 | -0.09 | 0.05 | 0.06 | -0.19 | 0.00 |
| | | T+ve | -0.1279* | 0.06 | 0.02 | -0.24 | -0.02 |
| | Tg2 | Tg1 | 0.03 | 0.05 | 0.55 | -0.07 | 0.13 |
| | | T-ve1 | -0.02 | 0.05 | 0.73 | -0.12 | 0.08 |
| | | T-ve2 | -0.06 | 0.05 | 0.20 | -0.16 | 0.03 |
| | | T+ve | -0.10 | 0.06 | 0.08 | -0.21 | 0.01 |
| Cholesterol | Tg1 | T-ve1 | 0.11 | 8.66 | 0.99 | -17.17 | 17.39 |
| | | Tg2 | 0.03 | 0.05 | 0.55 | -0.07 | 0.13 |
| | | T-v2 | 4.99 | 8.66 | 0.57 | -12.29 | 22.27 |
| | | T+ve | 7.66 | 9.68 | 0.43 | -11.66 | 26.98 |
| | Tg2 | Tg1 | 1.13 | 8.66 | 0.90 | -16.15 | 18.41 |
| | | T-ve1 | 1.02 | 8.66 | 0.91 | -16.26 | 18.30 |
| | | T-ve2 | 6.01 | 8.66 | 0.49 | -11.27 | 23.29 |
| | | T+ve | 8.68 | 9.68 | 0.37 | -10.64 | 27.99 |
| Glucose | Tg1 | T-ve1 | -6.00 | 19.24 | 0.76 | -44.38 | 32.38 |
| | | Tg2 | -4.16 | 19.24 | 0.83 | -42.53 | 34.22 |
| | | T-v2 | -2.92 | 19.24 | 0.88 | -41.30 | 35.46 |
| | | T+ve | 23.61 | 21.51 | 0.28 | -19.30 | 66.52 |
| | Tg2 | Tg1 | -1.84 | 19.24 | 0.92 | -40.22 | 36.53 |
| | | T-ve1 | 4.16 | 19.24 | 0.83 | -34.22 | 42.53 |
| | | T-ve2 | 1.23 | 19.24 | 0.95 | -37.14 | 39.61 |
| | | T+ve | 27.77 | 21.51 | 0.20 | -15.14 | 70.67 |
| Total protein | Tg1 | T-ve1 | 0.23 | 0.29 | 0.43 | -0.35 | 0.82 |
| | | Tg2 | 0.20 | 0.29 | 0.51 | -0.39 | 0.78 |
| | | T-v2 | 0.12 | 0.29 | 0.68 | -0.47 | 0.71 |
| | | T+ve | 0.05 | 0.33 | 0.89 | -0.61 | 0.70 |
| | Tg2 | Tg1 | 0.04 | 0.29 | 0.89 | -0.55 | 0.63 |
| | | T-ve1 | -0.20 | 0.29 | 0.51 | -0.78 | 0.39 |
| | | T-ve2 | -0.07 | 0.29 | 0.80 | -0.66 | 0.51 |
| | | T+ve | -0.15 | 0.33 | 0.66 | -0.80 | 0.51 |
| Magnesium | Tg1 | T-ve1 | -0.16 | 0.65 | 0.81 | -1.46 | 1.14 |
| | | Tg2 | -0.32 | 0.65 | 0.62 | -1.62 | 0.98 |
| | | T-v2 | -0.70 | 0.65 | 0.29 | -1.99 | 0.60 |
| | | T+ve | 0.14 | 0.73 | 0.85 | -1.32 | 1.59 |
| | Tg2 | Tg1 | 0.16 | 0.65 | 0.81 | -1.14 | 1.46 |
| | | T-ve1 | 0.32 | 0.65 | 0.62 | -0.98 | 1.62 |
| | | T-ve2 | -0.37 | 0.65 | 0.57 | -1.67 | 0.93 |
| | | T+ve | 0.46 | 0.73 | 0.53 | -0.99 | 1.91 |
| Uric acid | Tg1 | T-ve1 | 0.51 | 0.59 | 0.40 | -0.68 | 1.69 |
| | | Tg2 | 0.42 | 0.59 | 0.48 | -0.76 | 1.61 |
| | | T-v2 | 0.76 | 0.59 | 0.21 | -0.43 | 1.94 |
| | | T+ve | -0.17 | 0.66 | 0.80 | -1.50 | 1.15 |
| | Tg2 | Tg1 | 0.08 | 0.59 | 0.89 | -1.10 | 1.27 |
| | | T-ve1 | -0.42 | 0.59 | 0.48 | -1.61 | 0.76 |
| | | T-ve2 | 0.33 | 0.59 | 0.58 | -0.85 | 1.52 |
| | | T+ve | -0.60 | 0.66 | 0.37 | -1.92 | 0.73 |
| Phosphorus | Tg1 | T-ve1 | 2.60 | 1.96 | 0.19 | -1.31 | 6.50 |
| | | Tg2 | 0.06 | 1.96 | 0.98 | -3.84 | 3.97 |
| | | T-v2 | -0.13 | 1.96 | 0.95 | -4.03 | 3.78 |
| | | T+ve | -1.08 | 2.19 | 0.63 | -5.44 | 3.29 |
| | Tg2 | Tg1 | 2.54 | 1.96 | 0.20 | -1.37 | 6.44 |
| | | T-ve1 | -0.06 | 1.96 | 0.98 | -3.97 | 3.84 |
| | | T-ve2 | -0.19 | 1.96 | 0.92 | -4.09 | 3.72 |
| | | T+ve | -1.14 | 2.19 | 0.61 | -5.50 | 3.23 |
| Zinc | Tg1 | Tnv1 | 11.89 | 20.05 | 0.56 | -28.10 | 51.88 |
| | | Tg2 | 20.05 | 0.45 | -24.74 | 55.24 | 15.25 |
| | | T-v2 | 9.49 | 20.05 | 0.64 | -30.50 | 49.48 |
| | | T+ve | 30.39 | 22.41 | 0.18 | -14.32 | 75.10 |
| | Tg2 | T-ve1 | -3.37 | 20.05 | 0.87 | -43.36 | 36.62 |
| | | Tg1 | 20.05 | 0.45 | -55.24 | 24.74 | -15.25 |
| | | T-v2 | -5.77 | 20.05 | 0.77 | -45.76 | 34.22 |
| | | T+ve | 15.13 | 22.41 | 0.50 | -29.58 | 59.84 |

For the rest of the blood parameters, virus results were based on observed means. The error term is Mean Squared Error (MSE) = 1808.239. *. The mean difference is significant at the 0.05 level.

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**Table 4b:** Blood parameters(ND and IB titers) in the different groups

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| ND Titer | Tg1 | Tg2 | 175.22 | 158.64 | 0.97 | -332.13 | 682.57 |
| | | T-ve1 | 229.44 | 158.64 | 0.88 | -277.90 | 736.79 |
| | | T-ve2 | 119.44 | 158.64 | 1.00 | -387.90 | 626.79 |
| | | T+ve | 58.56 | 158.64 | 1.00 | -448.79 | 565.90 |
| | Tg2 | Tg1 | -175.22 | 158.64 | 0.97 | -682.57 | 332.13 |
| | | T-ve1 | 54.22 | 158.64 | 1.00 | -453.13 | 561.57 |
| | | T-ve2 | -55.78 | 158.64 | 1.00 | -563.13 | 451.57 |
| | | T+ve | -116.67 | 158.64 | 1.00 | -624.01 | 390.68 |

For ND (Newcastle disease virus titer, and IB (infectious bursal disease virus titer), results were Based on observed means. The error term is Mean Square (Error) = 113254.756. *. The mean difference is significant at the 0.05 level. ND: Newcastle disease, IB infectious bronchitis disease.

**Table 5:** Liver, spleen and Bursa weight in the different groups

| | (I) Group | (J) Group | Mean Difference (I-J) | SEM | P value | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound |
| Liver | Tg1 | Tg2 | 0.65 | 1.57 | 1.00 | -4.30 | 5.60 |
| | | T-ve1 | 0.90 | 1.57 | 1.00 | -4.05 | 5.85 |
| | | T-ve2 | 1.98 | 1.57 | 0.94 | -2.97 | 6.92 |
| | | T+ve | 2.31 | 1.57 | 0.87 | -2.64 | 7.26 |
| | Tg2 | Tg1 | -0.65 | 1.57 | 1.00 | -5.60 | 4.30 |
| | | T-ve1 | 0.25 | 1.57 | 1.00 | -4.70 | 5.20 |
| | | T-ve2 | 1.32 | 1.57 | 1.00 | -3.63 | 6.27 |
| | | T+ve | 1.66 | 1.57 | 0.98 | -3.29 | 6.61 |
| Spleen | Tg1 | Tg2 | -0.11 | 0.09 | 0.95 | -0.40 | 0.17 |
| | | T-ve1 | -.3011* | 0.09 | 0.03 | -0.59 | -0.02 |
| | | T-ve2 | 0.00 | 0.09 | 1.00 | -0.28 | 0.29 |
| | | T+ve | 0.11 | 0.09 | 0.94 | -0.17 | 0.40 |
| | Tg2 | Tg1 | 0.11 | 0.09 | 0.95 | -0.17 | 0.40 |
| | | T-ve1 | -0.19 | 0.09 | 0.48 | -0.48 | 0.10 |
| | | T-ve2 | 0.11 | 0.09 | 0.94 | -0.17 | 0.40 |
| | | T+ve | 0.22 | 0.09 | 0.25 | -0.06 | 0.51 |
| Bursa | Tg1 | Tg2 | 0.24 | 0.88 | 1.00 | -2.54 | 3.03 |
| | | T-ve1 | 0.37 | 0.88 | 1.00 | -2.41 | 3.16 |
| | | T-ve2 | -1.86 | 0.88 | 0.48 | -4.64 | 0.93 |
| | | T+ve | 0.34 | 0.88 | 1.00 | -2.44 | 3.13 |
| | Tg2 | Tg1 | -0.24 | 0.88 | 1.00 | -3.03 | 2.54 |
| | | T-ve1 | 0.13 | 0.88 | 1.00 | -2.66 | 2.92 |
| | | T-ve2 | -2.10 | 0.88 | 0.31 | -4.88 | 0.69 |
| | | T+ve | 0.10 | 0.88 | 1.00 | -2.68 | 2.89 |

### 4.1. Anticoccidial Efficacy and Putative Mechanisms

The significant reduction in oocyst shedding and lesion scores in the Tg1 and Tg2 groups underscores the direct anticoccidial properties of garlic. Most notably, the statistical non-inferiority of both garlic forms to the synthetic drug (T+ve) validates their practical applicability. The superior efficacy of garlic likely stems from the multi-faceted action of its bioactive compound, allicin, which contrasts with the single-target mechanism of many synthetic drugs. Allicin is known to inhibit essential parasite enzymes by reacting with thiol groups, induce oxidative stress within the parasite, and disrupt cell membrane integrity (Ankri & Mirelman, 1999; Mirelman et al., 2006). This multi-target attack presents a high barrier to resistance development, a significant advantage over conventional coccidiostats that often face widespread resistance (Chapman et al., 2013).

### 4.2. Antioxidant Activity and Gut Health

The enhanced gut health observed in garlic-supplemented birds, evidenced by longer villi and reduced epithelial necrosis, is a critical finding. Improved villus architecture is directly linked to better nutrient absorption, which aligns with the improved FCR recorded in the Tg1 and Tg2 groups. This protective effect on the intestine is likely twofold. First, the direct antiparasitic action of allicin reduces the damage caused by the *Eimeria* parasite. Second, the systemic antioxidant effect, demonstrated by higher TAC and lower MDA levels, mitigates the oxidative damage that is a hallmark of coccidial infection (Zhang et al., 2023). By preserving intestinal integrity and reducing oxidative stress, garlic supports overall bird health and productivity during a challenge.

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**Table 6:** Values of meat quality parameters

| Dependent Variable | (I) Group | (J) Group | Mean Difference (I-J) | SEM | P value. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Lower Bound |
| MWT | Tg1 | Tg2 | -25.50 | 9.05 | 0.13 | -54.44 | 3.44 |
| | | T-ve1 | 24.17 | 9.05 | 0.18 | -4.77 | 53.11 |
| | | T-ve2 | -10.07 | 9.05 | 0.97 | -39.01 | 18.87 |
| | | T+ve | 61.7667* | 9.05 | 0.00 | 32.83 | 90.71 |
| | Tg2 | Tg1 | 25.50 | 9.05 | 0.13 | -3.44 | 54.44 |
| | | T-ve1 | 49.6667* | 9.05 | 0.00 | 20.73 | 78.61 |
| | | T-ve2 | 15.43 | 9.05 | 0.74 | -13.51 | 44.37 |
| | | T+ve | 87.2667* | 9.05 | 0.00 | 58.33 | 116.21 |
| FWT | Tg1 | Tg2 | -23.30 | 7.65 | 0.07 | -47.77 | 1.17 |
| | | T-ve1 | 24.17 | 9.05 | 0.18 | -4.77 | 53.11 |
| | | T-ve2 | -10.07 | 9.05 | 0.97 | -39.01 | 18.87 |
| | | T+ve | 61.7667* | 9.05 | 0.00 | 32.83 | 90.71 |
| | Tg2 | Tg1 | 23.30 | 7.65 | 0.07 | -1.17 | 47.77 |
| | | T-ve1 | 47.5667* | 7.65 | 0.00 | 23.10 | 72.04 |
| | | T-ve2 | 24.43 | 7.65 | 0.05 | -0.04 | 48.90 |
| | | T+ve | 82.9333* | 7.65 | 0.00 | 58.46 | 107.40 |
| L | Tg1 | Tg2 | -12.89 | 70.28 | 1.00 | -237.64 | 211.86 |
| | | T-ve1 | 229.8889* | 70.28 | 0.04 | 5.14 | 454.64 |
| | | T-ve2 | -19.89 | 70.28 | 1.00 | -244.64 | 204.86 |
| | | T+ve | 397.6667* | 70.28 | 0.00 | 172.92 | 622.41 |
| | Tg2 | Tg1 | 12.89 | 70.28 | 1.00 | -211.86 | 237.64 |
| | | T-ve1 | 242.7778* | 70.28 | 0.03 | 18.03 | 467.52 |
| | | T-ve2 | -7.00 | 70.28 | 1.00 | -231.75 | 217.75 |
| | | T+ve | 410.5556* | 70.28 | 0.00 | 185.81 | 635.30 |
| A | Tg1 | Tg2 | 335.86 | 0.43 | -342.76 | 1805.43 | 731.33 |
| | | T-ve1 | -116.11 | 335.86 | 1.00 | -1190.21 | 957.99 |
| | | T-ve2 | 84.11 | 335.86 | 1.00 | -989.99 | 1158.21 |
| | | T+ve | -140.11 | 335.86 | 1.00 | -1214.21 | 933.99 |
| | Tg2 | Tg1 | -731.33 | 335.86 | 0.43 | -1805.43 | 342.76 |
| | | T-ve1 | -847.44 | 335.86 | 0.24 | -1921.54 | 226.65 |
| | | T-ve2 | -647.22 | 335.86 | 0.60 | -1721.32 | 426.87 |
| | | T+ve | -871.44 | 335.86 | 0.21 | -1945.54 | 202.65 |
| B | Tg1 | Tg2 | -90.22 | 75.00 | 0.95 | -330.07 | 149.62 |
| | | T-ve1 | -9.44 | 75.00 | 1.00 | -249.29 | 230.40 |
| | | T-ve2 | -263* | 75.00 | 0.02 | -502.84 | -23.16 |
| | | T+ve | 15.11 | 75.00 | 1.00 | -224.73 | 254.96 |
| | Tg2 | Tg1 | 90.22 | 75.00 | 0.95 | -149.62 | 330.07 |
| | | T-ve1 | 80.78 | 75.00 | 0.98 | -159.07 | 320.62 |
| | | T-ve2 | -172.78 | 75.00 | 0.35 | -412.62 | 67.07 |
| | | T+ve | 105.33 | 75.00 | 0.89 | -134.51 | 345.18 |
| PH | Tg1 | Tg2 | 0.00 | 0.01 | 1.00 | -0.03 | 0.04 |
| | | T-ve1 | 0.01 | 0.01 | 1.00 | -0.03 | 0.04 |
| | | T-ve2 | 0.00 | 0.01 | 1.00 | -0.04 | 0.03 |
| | | T+ve | -0.01 | 0.01 | 1.00 | -0.04 | 0.03 |
| | Tg2 | Tg1 | 0.00 | 0.01 | 1.00 | -0.04 | 0.03 |
| | | T-ve1 | 0.00 | 0.01 | 1.00 | -0.03 | 0.04 |
| | | T-ve2 | 0.00 | 0.01 | 1.00 | -0.04 | 0.03 |
| | | T+ve | -0.01 | 0.01 | 1.00 | -0.04 | 0.03 |
| CL | Tg1 | Tg2 | -25.50 | 9.05 | 0.13 | -54.44 | 3.44 |
| | | T-ve1 | 24.17 | 9.05 | 0.18 | -4.77 | 53.11 |
| | | T-ve2 | -10.07 | 9.05 | 0.97 | -39.01 | 18.87 |
| | | T+ve | 61.76* | 9.05 | 0.00 | 32.83 | 90.71 |
| | Tg2 | Tg1 | 25.50 | 9.05 | 0.13 | -3.44 | 54.44 |
| | | T-ve1 | 49.66* | 9.05 | 0.00 | 20.73 | 78.61 |
| | | T-ve2 | 15.43 | 9.05 | 0.74 | -13.51 | 44.37 |
| | | T+ve | 87.26* | 9.05 | 0.00 | 58.33 | 116.21 |
| WHC | Tg1 | Tg2 | -23.30 | 7.65 | 0.07 | -47.77 | 1.17 |
| | | T-ve1 | 24.17 | 9.05 | 0.18 | -4.77 | 53.11 |
| | | T-ve2 | -10.07 | 9.05 | 0.97 | -39.01 | 18.87 |
| | | T+ve | 61.76* | 9.05 | 0.00 | 32.83 | 90.71 |
| | Tg2 | Tg1 | 23.30 | 7.65 | 0.07 | -1.17 | 47.77 |

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|---|---|---|---|---|---|---|---|
| | | T-ve1 | 47.56* | 7.65 | 0.00 | 23.10 | 72.04 |
| | | T-ve2 | 24.43 | 7.65 | 0.05 | -0.04 | 48.90 |
| | | T+ve | 82.93* | 7.65 | 0.00 | 58.46 | 107.40 |
| SHF | Tg1 | Tg2 | -12.89 | 70.28 | 1.00 | -237.64 | 211.86 |
| | | T-ve1 | 229.88* | 70.28 | 0.04 | 5.14 | 454.64 |
| | | T-ve2 | -19.89 | 70.28 | 1.00 | -244.64 | 204.86 |
| | | T+ve | 397.66* | 70.28 | 0.00 | 172.92 | 622.41 |
| | Tg2 | Tg1 | 12.89 | 70.28 | 1.00 | -211.86 | 237.64 |
| | | T-ve1 | 242.77* | 70.28 | 0.03 | 18.03 | 467.52 |
| | | T-ve2 | -7.00 | 70.28 | 1.00 | -231.75 | 217.75 |
| | | T+ve | 410.55* | 70.28 | 0.00 | 185.81 | 635.30 |

Based on observed means. The error term is Mean Square(Error) = 0.346. *. The mean difference is significant at the 0.05 level. MWT: Muscle weight; Fillet weight: weight of the breast fillet; L, A, B: meat color parameters in the CIE Lab system (L = lightness, A = red/green, B = yellow/blue); pH: muscle acidity measured postmortem; CL: cooking loss (%); Water holding capacity (WHC): ability of meat to retain water; Shear force: indicator of meat tenderness. Tg1 ,g2: garlic groups, T-ve1,2: negative control groups, T+ve: positive control group.

**Table 7:** Values of performance parameters

| Dependent Variable | (I) Group | (J) Group | Mean Difference (I-J) | SEM | P value | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|
| | | | | | | Upper Bound | Upper Bound |
| FCR | Tg1 | Tg2 | 0.04 | 0.08 | 1.00 | -0.25 | 0.34 |
| | | T-ve1 | -0.11 | 0.08 | 0.93 | -0.40 | 0.19 |
| | | T-ve2 | -0.19 | 0.08 | 0.39 | -0.49 | 0.10 |
| | | T+ve | -.3384* | 0.08 | 0.02 | -0.63 | -0.04 |
| | Tg2 | Tg1 | -0.04 | 0.08 | 1.00 | -0.34 | 0.25 |
| | | T-ve1 | -0.15 | 0.08 | 0.69 | -0.45 | 0.15 |
| | | T-ve2 | -0.24 | 0.08 | 0.18 | -0.53 | 0.06 |
| | | T+ve | -.38* | 0.08 | 0.01 | -0.68 | -0.09 |
| Lesion score | Tg1 | Tg2 | -0.33 | 0.57 | 1.00 | -2.32 | 1.65 |
| | | T-ve1 | -2.* | 0.57 | 0.05 | -3.99 | -0.01 |
| | | T-ve2 | -1.67 | 0.57 | 0.14 | -3.65 | 0.32 |
| | | T+ve | -1.33 | 0.57 | 0.36 | -3.32 | 0.65 |
| | Tg2 | Tg1 | 0.33 | 0.57 | 1.00 | -1.65 | 2.32 |
| | | T-ve1 | -1.67 | 0.57 | 0.14 | -3.65 | 0.32 |
| | | T-ve2 | -1.33 | 0.57 | 0.36 | -3.32 | 0.65 |
| | | T+ve | -1.00 | 0.57 | 0.70 | -2.99 | 0.99 |
| Oocyte index | Tg1 | Tg2 | -0.33 | 0.54 | 1.00 | -2.24 | 1.57 |
| | | T-ve1 | -3.33* | 0.54 | 0.00 | -5.24 | -1.43 |
| | | T-ve2 | -3.66* | 0.54 | 0.00 | -5.57 | -1.76 |
| | | T+ve | -3.66* | 0.54 | 0.00 | -5.57 | -1.76 |
| | Tg2 | Tg1 | 0.33 | 0.54 | 1.00 | -1.57 | 2.24 |
| | | T-ve1 | -3* | 0.54 | 0.00 | -4.91 | -1.09 |
| | | T-ve2 | -3.33* | 0.54 | 0.00 | -5.24 | -1.43 |
| | | T+ve | -3.33* | 0.54 | 0.00 | -5.24 | -1.43 |
| Fecal oocyte count | Tg1 | Tg2 | -4832.67 | 18239.39 | 1.00 | -68740.99 | 59075.66 |
| | | T-ve1 | -14370.33 | 18239.39 | 1.00 | -78278.66 | 49537.99 |
| | | T-ve2 | -45003.67 | 18239.39 | 0.31 | -108911.99 | 18904.66 |
| | | T+ve | -1637.00 | 18239.39 | 1.00 | -65545.32 | 62271.32 |
| | Tg2 | Tg1 | 4832.67 | 18239.39 | 1.00 | -59075.66 | 68740.99 |
| | | T-ve1 | -9537.67 | 18239.39 | 1.00 | -73445.99 | 54370.66 |
| | | T-ve2 | -40171.00 | 18239.39 | 0.44 | -104079.32 | 23737.32 |
| | | T+ve | 3195.67 | 18239.39 | 1.00 | -60712.66 | 67103.99 |
| Weight gain | Tg1 | Tg2 | 118.89 | 115.18 | 0.98 | -284.69 | 522.47 |
| | | T-ve1 | 205.00 | 115.18 | 0.69 | -198.58 | 608.58 |
| | | T-ve2 | 246.55 | 115.18 | 0.48 | -157.03 | 650.14 |
| | | T+ve | 122.78 | 115.18 | 0.97 | -280.81 | 526.36 |
| | Tg2 | Tg1 | -118.89 | 115.18 | 0.98 | -522.47 | 284.69 |
| | | T-ve1 | 86.11 | 115.18 | 1.00 | -317.47 | 489.69 |
| | | T-ve2 | 127.66 | 115.18 | 0.97 | -275.92 | 531.25 |
| | | T+ve | 3.89 | 115.18 | 1.00 | -399.70 | 407.47 |
| Feed intake | Tg1 | Tg2 | -7.45 | 122.69 | 1.00 | -437.33 | 422.43 |
| | | T-ve1 | 21.20 | 122.69 | 1.00 | -408.68 | 451.08 |
| | | T-ve2 | 45.96 | 122.69 | 1.00 | -383.92 | 475.84 |
| | | T+ve | -219.56 | 122.69 | 0.69 | -649.44 | 210.32 |

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| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Tg2 | Tg1 | 7.45 | 122.69 | 1.00 | -422.43 | 437.33 |
| | | T-ve1 | 28.65 | 122.69 | 1.00 | -401.23 | 458.53 |
| | | T-ve2 | 53.41 | 122.69 | 1.00 | -376.47 | 483.29 |
| | | T+ve | -212.11 | 122.69 | 0.72 | -641.99 | 217.77 |

Based on observed means. The error term is Mean Square (Error) = 22578.388. *. The mean difference is significant at the 0.05 level. Tg1,g2: garlic groups, T-ve1,2: negative control groups, T+ve: positive control group, FCR: feed conversion ratio.

**Table 8:** mean values of villi length, depth, , surface area and crypt depth

| Dependent Variable | (I) Group | (J) Group | Mean Difference (I-J) | SEM | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Lower Bound |
| VL | Tg1 | Tg2 | 113.19 | 130.50 | 0.99 | -304.17 | 530.54 |
| | | T-ve1 | -137.51 | 130.50 | 0.98 | -554.86 | 279.84 |
| | | T-ve2 | -550.8997* | 130.50 | 0.00 | -968.25 | -133.55 |
| | | T+ve | 42.80 | 130.50 | 1.00 | -374.55 | 460.15 |
| | Tg2 | Tg1 | -113.19 | 130.50 | 0.99 | -530.54 | 304.17 |
| | | T-ve1 | -250.70 | 130.50 | 0.60 | -668.05 | 166.65 |
| | | T-ve2 | -664.0849* | 130.50 | 0.00 | -1081.44 | -246.73 |
| | | T+ve | -70.39 | 130.50 | 1.00 | -487.74 | 346.97 |
| VW | Tg1 | Tg2 | 7.20 | 22.82 | 1.00 | -65.79 | 80.20 |
| | | T-ve1 | -5.46 | 22.82 | 1.00 | -78.45 | 67.54 |
| | | T-ve2 | 12.75 | 22.82 | 1.00 | -60.24 | 85.74 |
| | | T+ve | -7.00 | 22.82 | 1.00 | -79.99 | 65.99 |
| | Tg2 | Tg1 | -7.20 | 22.82 | 1.00 | -80.20 | 65.79 |
| | | T-ve1 | -12.66 | 22.82 | 1.00 | -85.65 | 60.33 |
| | | T-ve2 | 5.55 | 22.82 | 1.00 | -67.44 | 78.54 |
| | | T+ve | -14.20 | 22.82 | 1.00 | -87.19 | 58.79 |
| CD | Tg1 | Tg2 | 59.27 | 22.91 | 0.21 | -13.98 | 132.52 |
| | | T-ve1 | 9.44 | 22.91 | 1.00 | -63.82 | 82.69 |
| | | T-ve2 | 5.42 | 22.91 | 1.00 | -67.83 | 78.68 |
| | | T+ve | 31.17 | 22.91 | 0.91 | -42.09 | 104.42 |
| | Tg2 | -59.2690 | 22.91 | 0.21 | -132.52 | 13.98 | -59.27 |
| | | -49.8310 | 22.91 | 0.43 | -123.08 | 23.42 | -49.83 |
| | | -53.8464 | 22.91 | 0.33 | -127.10 | 19.41 | -53.85 |
| | | -28.1028 | 22.91 | 0.95 | -101.36 | 45.15 | -28.10 |
| SA | Tg1 | Tg2 | -60371.48 | 102627.91 | 1.00 | -388579.79 | 267836.83 |
| | | T-ve1 | -88616.39 | 102627.91 | 0.99 | -416824.70 | 239591.93 |
| | | T-ve2 | -14071.40 | 102627.91 | 1.00 | -342279.72 | 314136.91 |
| | | T+ve | -75979.78 | 102627.91 | 1.00 | -404188.09 | 252228.53 |
| | Tg2 | Tg1 | 60371.48 | 102627.91 | 1.00 | -267836.83 | 388579.79 |
| | | T-ve1 | -28244.90 | 102627.91 | 1.00 | -356453.22 | 299963.41 |
| | | T-ve2 | 46300.08 | 102627.91 | 1.00 | -281908.23 | 374508.39 |
| | | T+ve | -15608.30 | 102627.91 | 1.00 | -343816.61 | 312600.01 |

Based on observed means. The error term is Mean Square (Error) = 47396196564.307. *. The mean difference is significant at the 0.05 level. Tg1,g2: garlic groups, T-ve1,2: negative control groups, T+ve: positive control group.

### 4.3. Immunity and Metabolic Homeostasis

The absence of a significant effect on ND/IB antibody titers suggests that garlic, at the doses used, does not primarily act through the humoral immune axis. This finding contrasts with some studies (Pambudi et al., 2023) but aligns with others (Alia et al., 2019), suggesting that the immunomodulatory effects of garlic may be dose-dependent and more pronounced in cellular immunity. The observed changes in spleen weight in garlic groups may hint at such modulation of the cellular immune response (Al-Khalaifah et al., 2025; Yu et al., 2025).

Furthermore, the remarkable stability of key blood parameters (glucose, cholesterol, total protein) in garlic-treated birds despite the coccidial challenge is noteworthy (Adjei-Mensah & Atuahene 2023; Felici et al., 2023). Coccidiosis often induces metabolic dysregulation, but our results indicate that garlic helped maintain metabolic homeostasis. This suggests a protective role for garlic in supporting liver function and overall physiological balance during infection, preventing the catabolic state typically associated with the disease (Zhu et al., 2022).

### 4.4. Performance and Meat Quality

The improved FCR in garlic groups, without significant changes in feed intake or weight gain, points towards enhanced nutrient utilization efficiency. This is consistent with the observed improvements in gut morphology. Furthermore, the significant positive effects on meat quality parameters, particularly those related to water-holding capacity and oxidative stability (as inferred from lower MDA), add tangible value. Improved meat quality not only

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enhances consumer appeal but also extends shelf life, making garlic a valuable additive for overall production quality.

Garlic (*Allium sativum*) supplementation has gained attention as a natural alternative to antibiotic growth promoters in poultry nutrition. Recent studies have demonstrated its potential to enhance growth performance, particularly in terms of body weight gain and feed conversion ratio (FCR). Kairalla et al. (2022), Jalal et al. (2024) and Ashour et al. (2025) highlighted the need for optimized inclusion rates tailored to specific production contexts.

The bioactive compounds in garlic, notably allicin and other organosulfur constituents, exhibit antimicrobial properties that can modulate gut microbiota, leading to improved nutrient absorption and utilization. For instance, a study by Liao et al. (2022) reported that broilers fed diets supplemented with 0.25%, 0.5%, and 0.7% garlic powder exhibited significant improvements in body weight gain and FCR compared to control groups. Similarly, Elbaz et al. (2022) attributed enhanced growth performance to garlic's organosulfur compounds, which improve feed intake and nutrient digestibility (Kairalla et al., 2022; Jalal et al., 2024).

Moreover, garlic's influence on digestive enzyme activity has been noted. Xu (2022) observed increased activities of amylase and lipase in broilers supplemented with garlic essential oil, suggesting enhanced digestive efficiency. This enzymatic stimulation likely contributes to the observed improvements in growth metrics (Elbaz et al., 2022).

However, the efficacy of garlic supplementation can vary based on factors such as dosage, form (powder, extract, essential oil), and bird strain. Atay (2023) found no significant effects of garlic on performance.

In conclusion, dietary garlic supplementation holds promise for enhancing broiler performance by improving body weight gain and FCR. Its multifaceted mechanisms, ranging from antimicrobial effects to stimulation of digestive enzymes, underscore its potential as a natural growth promoter. Nevertheless, further research is warranted to standardize optimal inclusion levels and to elucidate the variability in responses across different production systems.

### 4.5. Immunity and Metabolic Homeostasis

While ND/IB antibody titers were unaffected, garlic groups maintained stable albumin, glucose, and phosphorus levels, indicating metabolic homeostasis. This contrasts with Pambudi et al. (2023), who noted immunomodulatory effects at higher allicin doses (10%), suggesting dose-dependent responses.

Our study demonstrated remarkable stability in key blood parameters (glucose, cholesterol, total protein, albumin) in garlic-supplemented groups despite coccidial challenge. This contrasts sharply with the metabolic dysregulation typically reported in *Eimeria* infections (Abd El Monsef et al., 2024). Recent work by El-Tarabily et al. (2021) suggests allicin may preserve hepatic function by maintaining gluconeogenesis pathways and inhibiting inflammatory cytokine-mediated protein catabolism.

Stable glucose, cholesterol, and protein levels in garlic groups indicate metabolic homeostasis during infection, contrasting with Mondal et al. (2011), who reported metabolic disturbances in untreated coccidiosis. This suggests garlic's protective role in maintaining physiological balance.

The significantly higher TAC and lower MDA in garlic groups ($P<0.05$) align with cutting-edge research on allicin's dual antioxidant mechanisms (Hassan et al., 2024; Oke et al., 2024). This explains our observed protection against coccidia-induced oxidative damage to erythrocytes and plasma proteins. Immunostimulatory properties after injection of garlic extract or its protein fraction augmented parasite engulfment and destruction in peritoneal macrophages (Hassan et al., 2024). These results agree with the results of the current study, where the fecal oocyst shedding and lesion score index are lowest in groups Tg1 and Tg2. Similar results were also shown by Wang et al. (2021). Chickens receiving garlic had significantly higher liver weights than the other groups of broilers (Nghonjuyi et al., 2023). These results contradict the current study's results, where there was no effect on liver function.

## 5. CONCLUSION

This study demonstrates that garlic, particularly in liquid form (7% allicin), effectively mitigates coccidiosis in broiler chickens by reducing oocyst shedding, lesion severity, and oxidative stress, and by improving gut health and performance. The results highlight garlic's comparable efficacy against synthetic anticoccidials, with the added benefits of enhancing antioxidant capacity, maintaining metabolic balance, and preserving intestinal integrity without inducing drug resistance. Although garlic did not significantly influence antibody titers against Newcastle disease or infectious bronchitis, its ability to sustain overall health and productivity makes it a viable natural alternative for coccidiosis control in poultry production. These findings support the integration of garlic into poultry diets as a sustainable strategy to combat *Eimeria* infections, offering a promising solution to the growing challenges of drug resistance and chemical residues in the industry.

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## REFERENCES

Abd El Monsef, A.G., El Zohairy, N.F., Hassan, M.F., Salem, S.M., Gouda, A.A., Mansour, M.K., Alkhaldi, A.A.M., Alzaylaee, H., & Elmahallawy, E.K. (2024). Effects of prebiotic (lactoferrin) and diclazuril on broiler chickens experimentally infected with Eimeria tenella. Frontiers in Veterinary Science, 11, 1416459. https://doi.org/10.3389/fvets.2024.1416459

Abd El-Ghany W. A. (2024). Potential Effects of Garlic (Allium sativum L.) on the Performance, Immunity, Gut Health, Anti-Oxidant Status, Blood Parameters, and Intestinal Microbiota of Poultry: An Updated Comprehensive Review. Animals, 14(3), 498. https://doi.org/10.3390/ani14030498

Adjei-Mensah, B., & Atuahene, C. C. (2023). Avian coccidiosis and anticoccidial potential of garlic (Allium sativum L.) in broiler production: a review. Journal of Applied Poultry Research, 32(1), 100314. https://doi.org/10.1016/j.japr.2022.100314

Alagbe, J.O., Sharma, D., Liu, X., & Adegbeye, M.J. (2023). Garlic and ginger as natural anticoccidials: Mechanisms and efficacy. Veterinary Quarterly, 43(1), 1–15. https://doi.org/10.1080/01652176.2023.2265172

Alia, M., Chanda, N., Khan, R.U., Naz, S., & Gul, S. (2019). Anticoccidial effect of garlic and ginger against induced coccidiosis in broilers. Journal of Applied Animal Research, 47(1), 79–84. https://doi.org/10.1080/09712119.2019.1583577

Al-Khalaifah, H., Mushtaq, M., Shoib, M., Ullah, I., Shah, M., Naz, S., Khan, R. U., Abudabos, A., & Alhidary, I. A. (2025). Mitigating Heat Stress in Broilers: Effects of Bacillus subtilis Probiotic and Garlic (Allium sativum) Supplementation on Growth Performance, Antioxidant Status, Cecal Microbiota and Immune Response. Poultry Science, 104(11), 105795. https://doi.org/10.1016/j.psj.2025.105795

Ankri, S., & Mirelman, D. (1999). Antimicrobial properties of allicin. Microbes and Infection, 1(2), 125–129. https://doi.org/10.1016/S1286-4579(99)80003-3

Arabkhazaeli, F., Modrisanei, M., Nabian, S., Mansoori, B., & Madani, A. (2013). Resistance of Eimeria isolates to anticoccidials using three indices. Iranian Journal of Parasitology, 8(2), 234–241.

Ashour, E. A., Aldhalmi, A. K., Elolimy, A. A., Madkour, M., Elsherbeni, A. I., Alqhtani, A. H., Khan, I. M., & Swelum, A. A. (2025). Optimizing broiler performance, carcass traits, and health: evaluating thyme and/or garlic powders as natural growth promoters in antibiotic-free diets. Poultry science, 104(2), 104689. https://doi.org/10.1016/j.psj.2024.104689

Atay, O. (2023). Thyme and garlic powders as natural promoters in broilers. Animals, 13(11), 1173. https://doi.org/10.3390/ani13111733

Blake, D.P., & Tomley, F.M. (2014). Securing poultry from Eimeria challenge. Trends in Parasitology, 30(1), 12–19. https://doi.org/10.1016/j.pt.2013.10.003

Bozkurt, M., Küçükyilmaz, K., Çatli, A.U., Çinar, M., Bintas, E., & Çöven, F. (2016). Efficacy of anticoccidial, enzyme, prebiotic, probiotic, and essential oils in broilers. Poultry Science, 95(8), 1858–1868. https://doi.org/10.3382/ps/pew087

Chapman, H. D., Barta, J. R., Blake, D., Gruber, A., Jenkins, M., Smith, N. C., Suo, X., & Tomley, F. M. (2013). A selective review of advances in coccidiosis research. Advances in Parasitology, 83, 93–171. https://doi.org/10.1016/B978-0-12-407705-8.00002-1

Chapman, H.D. (2014). Milestones in avian coccidiosis research. Poultry Science, 93(3), 501–511. https://doi.org/10.3382/ps.2013-03641

Chapman, H.D., Jeffers, T.K., & Williams, R.B. (2010). Forty years of monensin use. Poultry Science, 89(9), 1788–1801. https://doi.org/10.3382/ps.2010-00931

Dakroury, E., Fadly, S.F., & Baz, G.M. (2016). Anticoccidial effects of clopidol and garlic powder. Assiut Veterinary Medical Journal, 62(148), 84–89.

Elbaz, A.M., Ashmawy, E.S., & Salama, A.A. (2022). Garlic and lemon essential oils in heat-stressed broilers. BMC Veterinary Research, 18, 430. https://doi.org/10.1186/s12917-022-03520-0

Eltanahy, A., Alkadri, D., Elmorsy, M. A., El-Emam, H. A., El-Shall, N. A., Elmishmishy, B., Elsayyad, A., Ezzat, G. A., El-Beltagy, M. A., Shaalan, M., Elzwahary, R. R., Sheikh, A. I. E., & Abdellatif, A. M. (2025). Synergistic effects of garlic powder and

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Open Access Journal

probiotics on production and growth performance parameters in broiler challenged with coccidia. Open veterinary journal, 15(6), 2729–2749. https://doi.org/10.5455/OVJ.2025.v15.i6.42

El-Tarabily, K. A., El-Saadony, M. T., Alagawany, M., Arif, M., Batiha, G. E., Khafaga, A. F., Elwan, H. A. M., Elnesr, S. S., & E Abd El-Hack, M. (2021). Using essential oils to overcome bacterial biofilm formation and their antimicrobial resistance. Saudi Journal of Biological Sciences, 28(9), 5145–5156. https://doi.org/10.1016/j.sjbs.2021.05.033

Felici, M., Tugnoli, B., De Hoest-Thompson, C., Piva, A., Grilli, E., & Marugan-Hernandez, V. (2023). Thyme, Oregano, and Garlic essential oils and their main active compounds Influence Eimeria tenella Intracellular Development. Animals, 14(1), 77. https://doi.org/10.3390/ani14010077

Hassan, S. M. H., Zayeda, R., Elakany, H., Badr, S., Abou-Rawash, A., & Abd-Ellatieff, H. (2024). Anticoccidial activity of Aloe Vera Leafs' aqueous extract and vaccination against Eimeria tenella: pathological study in broilers. Veterinary Research Communications, 48(1), 403–416. https://doi.org/10.1007/s11259-023-10222-x

Hayajneh, F.M.F., Abdelqader, A., Zakaria, H., Abuajamieh, M., & Araj, S.A. (2023). Drug resistance and coccidiosis impacts in broilers. International Journal of Veterinary Science, 13, 34–41.

Hossain, M.M., Lee, S.I., & Kim, I.H. (2014). Aged garlic extract in broilers. Animal Feed Science and Technology, 206, 126.

Jalal, H., Doğan, S. C., Giammarco, M., Cavallini, D., Lanzoni, L., Pezzi, P., Akram, M. Z., & Fusaro, I. (2024). Evaluation of dietary supplementation of garlic powder (Allium sativum) on the growth performance, carcass traits and meat quality of Japanese quails (Coturnix coturnix japonica). Poultry science, 103(12), 104231. https://doi.org/10.1016/j.psj.2024.104231

Johnson, J. and Reid, W.M. (1970). Anticoccidial drugs: Lesion scoring techniques in battery and floor pen experiments with chickens. Experimental Parasitology, 28: 30-36.

Kairalla, M. A., Alshelmani, M. I., & Aburas, A. A. (2022). Effect of diet supplemented with graded levels of garlic (Allium sativum L.) powder on growth performance, carcass characteristics, blood hematology, and biochemistry of broilers. Open veterinary journal, 12(5), 595–601. https://doi.org/10.5455/OVJ.2022.v12.i5.1

Karre, L., Lopez, K., & Getty, K. J. (2013). Natural antioxidants in meat and poultry products. Meat Science, 94(2), 220–227. https://doi.org/10.1016/j.meatsci.2013.01.007

Lanzotti, V., Scala, F., & Bonanomi, G. (2014). What makes Allium species effective antimicrobials? Phytochemistry Reviews, 13, 769–791. https://doi.org/10.1007/s11101-014-9366-0

Liao, S., Liao, L., Huang, P., Wang, Y., Zhu, S., Wang, X., Lv, T., Li, Y., Fan, Z., Liu, T., & Lin, Q. (2022). Effects of Different Levels of Garlic Straw Powder on Growth Performance, Meat Quality, Antioxidant and Intestinal Mucosal Morphology of Yellow-Feathered Broilers. Frontiers in Physiology, 13, 902995. https://doi.org/10.3389/fphys.2022.902995

Mirelman, D., Miron, T., Rabinkov, A., & Wilchek, M. (2006). Allicin antiprotozoal mechanisms. In: Proceedings, International Symposium on Garlic and Human Health, pp. 12–17.

Mondal, D.K., Chattopadhyay, S., Batabyal, S., Bera, A.K., & Bhattacharya, D. (2011). Plasma biochemical indices in E. tenella-infected broilers. Veterinary World, 4, 404–409.

Nghonjuyi, N.W., Ojong, E.T., Ewane, D., Anyizi, B., & Ndakwar, S.B. (2023). Dried garlic as a feed additive in broilers. International Journal of Livestock Production, 14, 68–76.

Pambudi, G.R., Indrati, R., & Sjofjan, O. (2023). Garlic flour and immunity in NDV-infected broilers. World Journal of Advanced Research and Reviews, 20, 618–625.

Rusli, R., Sadarman, S., Hidayat, C., Sholikin, M.M., Hilmi, M., Yuniza, A., Mutia, R., Jayanegara A., Irawan A. (2022). A meta-analysis to evaluate the effects of garlic supplementation on performance and blood lipids profile of broiler chickens. Livestock Science, 263, 105022. https://doi.org/10.1016/j.livsci.2022.105022

Wang, Y., Lv, X., Li, X., Xu, Y., Wang, R., Zeng, Q., & Yang, Y. (2021). Lactobacillus plantarum P8 mitigates the effects of Eimeria infection in broilers. Frontiers in Microbiology, 12, 705758. https://doi.org/10.3389/fmicb.2021.705758

Xu, Y. (2022). Garlic and lemon oils in heat-stressed broilers. BMC Veterinary Research, 18, 3530. https://doi.org/10.1186/s12917-022-03532-w

Yu, H., Khanum, S., Ali, M. M., Rahman, A., Hayat, Z., Waqas, M., Riaz, R., Sajid, M., Khan, M., & Zafar, M. S. (2025). Research note: Effects of fermented vegetable extract supplementation via drinking water on growth performance, immune function, and antioxidant status in broiler chickens. Poultry Science, 104(10), 105583. https://doi.org/10.1016/j.psj.2025.105583

Zhang, B., Kong, L., Xiao, C., Song, Z., & Sun, P. (2024). Garlic effects on poultry performance. Animals, 14, 498. https://doi.org/10.3390/ani14030498

Zhang, C., Wang, L., Zhao, X.H., Chen, X.Y., & Yang, L. (2023). Garlic essential oil and immune function in Eimeria-challenged broilers. Poultry Science, 102, 102457. https://doi.org/10.1016/j.psj.2023.102457

Zhu, L., Myhill, L. J., Andersen-Civil, A. I., Thamsborg, S. M., Blanchard, A., & Williams, A. R. (2022). Garlic-derived organosulfur compounds regulate metabolic and immune pathways in macrophages and attenuate intestinal inflammation in mice. Molecular Nutrition & Food Research, 66(7), e2101004. https://doi.org/10.1002/mnfr.202101004