Research Article

Impact of Curcumin and Nano-Curcumin Supplementation in Lead Acetate-Contaminated Diets on the Productive Performance and Oxidative Status of Broilers

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Abstract | Lead acetate is a toxic environmental contaminant that can impair growth performance and induce oxidative stress in poultry, highlighting the need for natural dietary interventions to mitigate its harmful effects. The objective of present study was to evaluate the effects of curcumin and nano-curcumin supplementation in broiler diets contaminated with lead acetate on productive performance and antioxidant status. A total of 180 unsexed, one-day-old Ross 308 broiler chicks were randomly allocated into six experimental groups, each with three replicates of ten birds that were reared for 42 days. The control group was fed a standard diet. A second group received the standard diet contaminated with lead acetate at 600 mg/kg of feed. Third group was fed the standard diet supplemented with curcumin at 800 mg/kg, while a fourth group received nano-curcumin at the same dosage. A fifth group was given the standard diet containing both curcumin (800 mg/kg) and lead acetate (600 mg/kg), and the final group received nano-curcumin (800 mg/kg) along with lead acetate (600 mg/kg). At the end of the experiment, antioxidant status was assessed through several indicators, including the activity of glutathione (GSH) in the blood and the levels of peroxide value (PV), free fatty acids (FFA), and malondialdehyde (MDA) in liver tissue. The results indicated that broilers supplemented with curcumin or nano-curcumin alone showed the best performance outcomes across most measured parameters. In contrast, the control group exhibited the lowest performance values at 42 days of age. Supplementation with curcumin or nano-curcumin significantly reduced the oxidative effects of lead acetate and mitigated its impact, thereby enhancing the productive performance of broilers.

Keywords | Broiler, Curcumin, Lead acetate, Nano-curcumin, Oxidative status, Productive performance

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INTRODUCTION

Lead, a significant environmental contaminant, is a naturally occurring element that has been widely dispersed in the environment due to human activities. Broilers can be exposed to lead through various pathways, including water, air, and feed (Naicker *et al.*, 2018). Studies have associated lead exposure with organ weight changes and liver damage in animals (Kim *et al.*, 2020). A reduction in the total erythrocyte count is related to both the duration and the concentration of lead acetate ingested. Furthermore, lead acetate elevates leukocyte numbers and alters the differential leukocyte count, potentially due to an increase in inflammatory responses (Offor *et al.*, 2017). Lead's toxicity manifests as morphological and biochemical alterations in various tissues, notably affecting the liver and kidneys (Wani *et al*., 2015). Serum enzyme levels serve as crucial indicators of chemically induced toxicity in animal studies. Research has shown that lead acetate increases the activity of serum enzymes such as alanine aminotransferase (ALT) and aspartate aminotransferase (AST), while reducing the activity of antioxidant enzymes including catalase (CAT), glutathione peroxidase (GPx), and superoxide dismutase (SOD) in mice (Khanam *et al*., 2016). Hematological parameters such as hemoglobin (Hb), mean corpuscular hemoglobin concentration (MCHC), and packed cell volume (PCV) are key indicators for assessing anemia in animals (Hasan *et al*., 2016). Rahman and Joshi (2009) found that the toxicity of lead acetate in broiler drinking water at concentrations of 250 and 400 ppm was directly correlated with the dosage, with the most pronounced effects observed during the final three weeks of the broilers' lifespan. With the increasing focus on sustainable and safe food production, there is a growing interest in exploring non-synthetic feed additives as a substitute for synthetic growth enhancers and antibiotics (Mahde and Hammod, 2024; Hameed and Mousa, 2025). Among these, herbal plants and nanotechnology-based additives have gained significant attention due to their potential to enhance broiler performance, improve feed efficiency, and promote overall health without the adverse effects associated with conventional additives (Al-Thuwaini *et al*., 2022). The use of medicinal plants as a strong antioxidant in the nutrition of laying hens has led to an improvement in their chemical properties (Jaber and Ali, 2023).

Herbal plants are valuable sources of bioactive contents, featuring a variety of substances like polyphenols, flavonoids, and essential oils, which exhibit antimicrobial, antioxidant, and immune-modulatory attributes (Mousa *et al*., 2020). These natural compounds can positively influence gut health, nutrient absorption, and metabolic processes in broilers, leading to improved growth achievement and feed conversion ratios (Hammod *et al*., 2020; Yousif *et al*., 2021). On the other side, nanotechnology offers innovative solutions by enhancing the bioavailability and stability of bioactive compounds through nano-encapsulation or nano-emulsification. Nanoparticles can also act as carriers for the targeted delivery of nutrients, further optimizing their utilization in broiler diets (Abbas and Ali, 2019).

The integration of herbal plants and nano-technological advancements in broiler nutrition represents a promising approach to address challenges such as antibiotic resistance, oxidative stress, and suboptimal growth performance or energy sources (Mousa *et al*., 2018a). This research aims to explore the synergistic effects of natural herbal additives and nano-technology in broiler diets, emphasizing their contribution to improving production efficiency, and promoting sustainable poultry farming practices, by leveraging the potential of these natural and innovative solutions, this study seeks to contribute to the development of safer and more effective feeding strategies for broiler production (Farhan *et al*., 2019). The use of natural alternatives, such as medicinal plants, as feed additives in poultry diets has been shown to enhance production performance. Among these is turmeric, also known as the 'yellow antidote,' a tropical plant widely distributed in regions such as India and Indonesia, and scientifically classified as *Curcuma longa.* The use of medicinal plants in the relationship of laying hens led to an improvement in sex hormones and hatching rate. Nano-technology provides an opportunity to mediate and solve some problems, as nano-particles possess various chemical and physical properties in comparison to other minerals (Al-Thuwaini *et al*., 2022). The use of medicinal plants in the diet of broiler breeder chickens led to an improvement in some biochemical and reproductive characteristics (Al-Zalzal and Ali, 2024). The use of different doses of nano-curcumin had a positive effect on some tissue characteristics of broiler mothers (Shakir and Ali, 2024). Through expanding the surface area of the minerals, bioavailability could be enhanced through the production of nanoparticles (Mohammadi *et al*., 2015). Recently, there has been increased interest in nano-technology applications, and their benefits and efficacy in livestock feed, despite the limited research and studies in this field regarding poultry feed (Fesseha *et al*., 2020). This is supported by the high solubility and absorption of nano-curcumin particles compared to conventional curcumin particles, which may be attributed to the high availability and bio accessibility of nano-particles (Song *et al*., 2011). Curcumin supplementation in broiler diets at levels of 250, 300, and 350 mg kg^{-1} significantly improved body weights, weight gains, and feed conversion ratios compared to a control group (El-Damrawy *et al*., 2024). Our study aimed to examine the effects of adding curcumin and nano-curcumin to broiler feeds and their impact on productive traits and oxidative stress.

MATERIALS AND METHODS

Broiler Welfare and Research Ethics

In a study on the effect of curcumin and nanocurcumin in poultry feed, the highest standards of scientific research ethics were adhered to, prioritizing the welfare of the broilers at all stages of the experiment while ensuring accurate and reliable scientific results that contribute to improving the health and productivity of the broilers. This study aims to achieve tangible benefits for the broilers while maintaining the highest standards of ethical care. Guidelines for the care of broilers were approved by the Ethics Committee of the College of Agriculture, Department of Animal Production, University of Anbar, Ministry of Higher Education and Scientific Research, Iraq (3314 dated 28/11/2023).

Table 1: Ingredient and Chemical composition of experimental diets.

Item%	Starter feed (1-10 day)	Grower feed (11-22 day)	Finisher feed (23-42 day)
Corn	55.5	60.4	64.8
Soybean 48%*	35.9	31	26
Protein Con.**	4	4	4
Vegetable Oil	2.2	2.67	3.6
Di Calcium Phosphate	0.7	0.5	0.3
limestone	1.3	1.1	1
Salt	0.1	0.1	0.1
DL-Meth.	0.18	0.14	0.12
Lysine	0.12	0.09	0.08
Total	100	100	100
Chemical analysis, Calculated* **			
Crude protein	23.2	21.5	19.30
ME (kcal)	3017	3101	3210
Methionine+ cysteine	1.09	0.99	0.91
Ether Extract	4.91	2.52	6.56
Crude Fiber	2.70	2.61	2.51
Lysine	1.45	1.30	1.16
Calcium	0.97	0.88	0.78
Available phosphorus	0.39	0.35	0.30

*Soybean meal 48% crude protein. **Each kilogram of this concentrate includes the following vitamins: Vitamin A: 100,000 IU, Vitamin D3: 33,000 IU, Vitamin E: 100 mg, Vitamin K3: 2.55 mg, Vitamin B1 (Thiamine): 25 mg, Vitamin B2 (Riboflavin): 10 mg, Vitamin B6 (Pyridoxine): 50 mg, Vitamin B12 (Cobalamin): 24 µg,Niacin: 51 mg, Folic Acid: 1.5 mg,Biotin: 15 µg, Pantothenic Acid: 13.5 mg. Additionally , Sodium: 2.5 mg, Threonine: 1.7 mg,Tryptophan: 0.42 mg,Choline: 4.2 mg. Metabolizable Energy: 2109 kcal/kg. ***The feed ingredients were calculated according to the recommendations of the National Research Council (NRC, 1994).

Experimental Design and Feeding Protocol

This study was carried out at the poultry farm affiliated with the Department of Animal Production, College of Agriculture, University of Anbar, spanning from November 28, 2023, to January 8, 2024. The primary objective was to evaluate and compare the effects of dietary supplementation with curcumin, nano-curcumin, and lead acetate on the productive performance of broilers. A total of 180 one-day-old broiler chicks (Ross 306) with an average initial body weight of 39 g were sourced from a commercial hatchery. Upon arrival, the chicks were weighed, wing-banded for identification, and evenly distributed into 18-floor pens (10 broilers per pen) to ensure uniformity in initial body weight across experimental groups. The chicks were randomly assigned to one of six dietary groups, with three replicates per group. The experiment was conducted over a 42-day period, during which the temperature was carefully regulated. The temperature was initially set at 35°C on the first day and gradually reduced to 22°C by the 21 days. The broilers were fed a three-phase diet: a starter diet (1–10) days, a grower diet (11–22) days, and a finisher diet (23–42) days. All diets were formulated to meet the nutritional requirements for young broilers as per established standards (NRC, 1994) and were provided in mash form. Each pen was equipped with a manual plastic feeder and an automatic nipple drinker, ensuring *ad libitum* access to feed and water throughout the experimental period. The detailed ingredients and chemical composition of diets are provided in Table 1.

Preparation of Nano-curcumin

Nano-curcumin was synthesized using a solvent-antisolvent precipitation technique. A solution of curcumin in ethanol (100 mg mL^{-1}) was rapidly introduced into water (ratio 1:10) under homogenization with an IKA T25 Ultra-Turrax for 20 minutes. The resulting precipitate was then dried by first reducing the supernatant via overnight incubation at 80°C, followed by freeze-drying at -110°C for 24 hours (Yadav and Neeraj, 2014). The final nano-curcumin powder was then stored in airtight containers for subsequent use. This process was performed in triplicate to ensure consistency.

Experimental Design

The dietary experimental groups were as follows:

G1 (Control): Standard feed with no additives.

G2 (Lead acetate group): Standard feed contaminated with 600 $mgkg^{-1}$ of lead acetate.

G3 (Curcumin group): Standard feed supplemented with 800 $mgkg^{-1}$ of curcumin.

G4 (Nano-curcumin group): Standard feed supplemented with 800 $mgkg^{-1}$ of nano-curcumin.

G5 (Curcumin + lead acetate group): Standard feed supplemented with 800 $mgkg^{-1}$ of curcumin and 600 $mgkg^{-1}$ of lead acetate.

G6 (Nano-curcumin + lead acetate group): Standard feed supplemented with 800 $mgkg^{-1}$ of Nano-curcumin and 600 $mgkg^{-1}$ of lead acetate.

Individual body weights and Feed Consumption (FC) were collected and recorded at the end of the week in sequence. The collected data and key performance metrics, including FC, Feed Conversion Ratio (FCR), and Body Weight Gain (BWG), were calculated to assess the productive performance of broilers across the different dietary groups.

Laboratory Analysis

At the end of the study (42 days), three broilers from each group were selected and slaughtered, and their livers were collected for the analysis of oxidative stress indicators. The activity of glutathione (GSH) enzyme in the liver was measured according to the method described by Wheeler and Nixon (1990). Malondialdehyde (MDA) levels were determined based on the procedure outlined by Witte *et al.* (1970). Additionally, the levels of free fatty acids (FFA) and peroxide value (P.V.) in the liver were assessed using the method described by Egan *et al.* (1981).

Statistical Analysis

The data obtained from this experiment were analyzed statistically by using the General Linear Model (GLM) procedure in Statistical Analysis System (SAS, 2001) software. Each pen was considered as the experimental unit for the analysis. To determine significant differences among the Experimental groups, Duncan's multiple-range test was applied. A significance level of ($P \leq 0.05$) was used to assess the statistical differences.

RESULTS

Live Weight

The results presented in Table 2 indicate that there were no significant differences in mean weekly body weight among the treatment groups during the first, second, third, fourth, and fifth weeks. However, a significant difference ($P \leq 0.05$) was observed during the sixth week. Broilers in Group 3 (G3), which received curcumin at 800 mg/kg feed, and Group 4 (G4), which received nano-curcumin at the same level, recorded significantly higher average live body weights of 2262.13 g and 2298.27 g, respectively. These values were significantly greater ($P \leq 0.05$) than those observed in Group 1 (G1; control: 2117.95 g), Group 2 (G2; lead acetate at 600 mg/kg feed: 2099.03 g), Group 5 (G5; curcumin + lead acetate, 800 + 600 mg/kg feed: 2140.25 g), and Group 6 (G6; nano-curcumin + lead acetate, 800 + 600 mg/kg feed: 2095.16 g). Additionally, no significant differences ($P \geq 0.05$) were found among G1, G2, G5, and G6 during the sixth week.

Body Weight Gain

Table 3 presents the statistical analysis of body weight gain in broilers fed diets supplemented with curcumin, nano-curcumin, and lead acetate. The results indicated that there were no significant differences in weekly body weight gain among the treatment groups during the first, second, third, fourth, and fifth weeks of the study. However, during the sixth week, broilers in Group 3 (G3) and Group 4 (G4), which received curcumin and nano-curcumin at 800 mg/kg feed respectively, showed higher weight gains of 414.81 g and 431.52 g per bird, respectively. These values were higher compared to those in Group 1 (G1; control: 373.82 g), Group 5 (G5; curcumin + lead acetate: 354.12 g), and Group 6 (G6; nano-curcumin + lead acetate: 357.62 g). Broilers in Group 2 (G2; lead acetate only) recorded a weight gain of 400.96 g, which did not differ significantly ($P \geq 0.05$) from those in G1, G3, and G4.

Furthermore, cumulative body weight gain from day 1 to day 42 showed that G3 and G4 achieved the highest gains, with values of 2223.13 g and 2259.27 g per bird, respectively. These gains were greater than those observed in G1, G2, G5, and G6, which recorded 2078.95 g, 2060.03 g, 2101.25 g, and 2056.16 g per bird, respectively. However,no significant differences ($P \geq 0.05$) were observed among G1, G2, G5, and G6 in cumulative body weight gain.

Table 2: Impact of supplementation of curcumin and nano-curcumin to broiler´s diets contaminated with lead acetate on live body weight (gm ± SE).

Weeks	Group						P-value
	G1	G2	G3	G4	G5	G6	
1	144.99±3.10	145.83±1.71	146.25±1.67	143.90±3.62	142.23±1.23	145.25±4.08	N.S
2	335.50±4.25	332.66±6.66	341.25±13.13	340.17±5.49	330.94±7.58	334.84±10.67	N.S
3	658.81±5.57	656.58±14.11	684.53±10.30	668.15±5.53	666.38±6.80	652.66±15.35	N.S
4	1167.66±17.62	1148.61±16.95	1197.58±4.09	1176.92±8.13	1155.03±30.82	1129.79±32.35	N.S
5	1744.13±18.48	1698.07±53.81	1847.32±9.32	1866.75±18.24	1786.13±25.74	1737.54±84.27	N.S
6	2117.95±64.53 B	2099.03±64.42B	2262.13±13.37A	2298.27 ±28.56A	2140.25±35.95B	2095.16±30.73B	0.05

Numbers indicate means ± standard errors. NS: Non-significant between Groups.Different letters within the same row indicate significant differences between the groups at a significance level ($P \leq 0.05$). G1: Control Group, G2: supplemented with lead acetate 600 mg kg^{-1} feed, G3: supplemented with curcumin 800mg kg^{-1} feed, G4: supplemented with nano-curcumin800mg kg^{-1} feed, G5: supplemented with curcumin 800mg kg^{-1} feed + lead acetate 600mg kg^{-1} feed, G6: supplemented with nano-curcumin800mg kg^{-1} feed + lead acetate 600mg kg^{-1} feed.

Table 3: Impact of supplementation of curcumin and nano-curcumin to broiler´s diets contaminated with lead acetate on body weight gain (gm $bird^{-1}$) ± SE.

Weeks	Group						P-value
	G1	G2	G3	G4	G5	G6	
1	105.99±3.10	106.83±1.71	107.24±1.67	104.9±3.17	103.23±4.08	106.25±1.23	N.S
2	190.50±5.74	186.83±4.55	195.01±11.54	196.27±1.84	188.71±10.00	189.59±8.35	N.S
3	323.31±8.00	323.92±8.14	343.28±2.97	327.98±10.49	335.44±17.16	317.82±12.36	N.S
4	508.85±18.29	492.03±27.57	513.05±9.00	508.77±29.24	488.65±17.33	477.13±27.83	N.S
5	576.47±33.77	549.47±41.70	649.74±5.87	689.83±4.92	631.10 ±68.60	607.75±15.67	N.S
6	373.82±54.59B	400.96±63.43AB	414.81±7.65A	431.52±5.66A	354.12±71.36C	357.62±51.44C	0.05
1-6weeks	2078.95±64.53B	2060.03±64.42B	2223.13±13.37A	2259.27±11.22A	2101.25±30.73B	2056.16±35.95B	0.05

Numbers indicate means ± standard errors. NS: Non-significant between Groups. Different letters within the same row indicate significant differences between the groups at a significance level (P≤0.05). G1: Control Group, G2: supplemented with lead acetate 600 mg kg^{-1} feed, G3: supplemented with curcumin 800mg kg^{-1} feed, G4: supplemented with nano-curcumin800mg kg^{-1} feed, G5: supplemented with curcumin 800mg kg^{-1} feed + lead acetate 600mg kg^{-1} feed, G6: supplemented with nano-curcumin800mg kg^{-1} feed + lead acetate 600mg kg^{-1} feed.

Table 4: Impact of supplementation of curcumin and nano-curcumin to broiler´s diets contaminated with lead acetate on feed consumption (gm $bird^{-1}$) ± SE.

Weeks	Group						P-value
	G1	G2	G3	G4	G5	G6	
1	111.67±4.72	113.00±2.46	106.83±2.78	109.33±4.18	113.25±5.32	113.69±3.56	N.S
2	278.42±9.82	304.08±5.58	275.33±0.78	280.63±5.34	279.33±7.92	304.71±10.87	N.S
3	512.50±11.46AB	533.31±12.03A	470.28±15.44C	475.05±5.07C	485.68±4.94BC	505.23±11.79ABC	0.05
4	724.84±23.69	753.70±25.11	697.82±27.44	701.10±8.34	696.57±12.49	691.46±9.46	N.S
5	925.89±25.78	919.61±20.36	864.66±30.00	870.92±11.95	909.60±11.85	917.28±24.72	N.S
6	835.25±21.12	849.86±43.53	842.49±30.68	844.32±25.33	907.03±39.11	859.36±58.33	N.S
1-6 weeks	3388.57±47.08 AB	3473.56±67.02A	3257.41±81.66B	3281.35±21.63B	3391.46±52.48AB	3391.73±63.52AB	0.05

Numbers indicate means ± standard errors. NS: Non-significant between Groups. Different letters within the same row indicate significant differences between the groups at a significance level (P≤0.05). G1: Control Group, G2: supplemented with lead acetate 600 mg kg^{-1} feed, G3: supplemented with curcumin 800mg kg^{-1} feed, G4: supplemented with nano-curcumin800mg kg^{-1} feed, G5: supplemented with curcumin 800mg kg^{-1} feed + lead acetate 600mg kg^{-1} feed, G6: supplemented with nano-curcumin800mg kg^{-1} feed + lead acetate 600mg kg^{-1} feed.

Feed Consumption

Table 4 presents the feed consumption values for broilers across the different treatment groups. No significant differences were observed among the groups during the first, second, fourth, fifth, and sixth weeks. However, significant differences (P ≤ 0.05) were detected during the third week of age. Broilers in Group 2 (G2), which received lead acetate, consumed the highest amount of feed at 533.31 g per bird, which was significantly higher than the feed intake recorded in Groups 3 (G3), 4 (G4), and 5 (G5), which consumed 470.28 g, 475.05 g, and 485.68 g per bird, respectively. Additionally, broilers in the control group (G1) recorded a feed intake of 512.50 g per bird, which was significantly higher than that of broilers in G3 and G4.

Cumulative feed consumption over the 42-day period also showed significant differences among the treatment groups. Broilers in G3 and G4 consumed significantly less feed, with values of 3257.41 g and 3281.35 g per bird, respectively, compared to broilers in G2, which recorded the highest cumulative intake of 3473.56 g per bird. However, this value did not differ significantly from the cumulative feed intake in G1, G5, and G6, which recorded 3388.57 g, 3391.46 g, and 3391.73 g per bird, respectively.

Feed Conversion Ratio

Table 5 presents the feed conversion ratio (FCR) of the experimental broiler groups. No significant differences (P ≥ 0.05) were observed among the groups during the first week. In the second week, broilers in Group 3 (G3; curcumin 800 mg/kg feed) and Group 4 (G4; nano-curcumin 800 mg/kg feed) showed significantly improved FCR values compared to those in Groups 1 (G1), 2 (G2), 5 (G5), and 6 (G6), which recorded FCRs of 1.46, 1.63, 1.48, and 1.61,

Table 5: Impact of supplementation of curcumin and nano-curcumin to broiler´s diets contaminated with lead acetate on feed conversion ratio (gm feed gm body weight gain^{-1}) ± SE.

Weeks	Groups						P-value
	G1	G2	G3	G4	G5	G6	
1	1.05±0.04	1.06±0.01	1.00±0.04	1.04±0.029	1.10±0.03	1.07±0.03	N.S
2	1.46±0.04AB	1.63±0.06A	1.41±0.09B	1.43± 0.032B	1.48±0.07AB	1.61±0.01A	0.05
3	1.59±0.07A	1.65±0.06A	1.37±0.05C	1.45± 0.058B	1.45±0.08B	1.59±0.05B	0.05
4	1.43±0.07B	1.53±0.07A	1.36±0.07C	1.38 ± 0.026C	1.43±0.07B	1.45±0.07AB	0.05
5	1.61±0.04A	1.67±0.10A	1.33±0.05BC	1.26 ± 0.039C	1.44±0.17B	1.51±0.02AB	0.05
6	2.23±0.51B	2.12±0.30BC	2.03±0.08B	1.96± 0.043C	2.56±0.59A	2.40±0.74AB	0.05
1-6 weeks	1.63±0.03A	1.67±0.02A	1.47±0.04B	1.45± 0.017B	1.61±0.03AB	1.65±0.05A	0.05

Numbers indicate means ± standard errors. NS: Non-significant between Groups. Different letters within the same row indicate significant differences between the groups at a significance level (P≤0.05). G1: Control Group, G2: supplemented with lead acetate 600 mg kg^{-1} feed, G3: supplemented with curcumin 800mg kg^{-1} feed, G4: supplemented with nano-curcumin800mg kg^{-1} feed, G5: supplemented with curcumin 800mg kg^{-1} feed + lead acetate 600mg kg^{-1} feed, G6: supplemented with nano-curcumin800mg kg^{-1} feed + lead acetate 600mg kg^{-1} feed.

respectively. During the third week, broilers in G3 exhibited the most efficient FCR at 1.37, significantly better than G5 and G6, which recorded 1.45 and 1.59, respectively. In the same week, broilers in G1 and G2 showed the poorest FCR values of 1.59 and 1.65, respectively.

In the fourth week, the best FCR values were again observed in G3 and G4 compared to the other groups. Similarly, during the fifth and sixth weeks, G4 continued to show superior FCR values, recording 1.96 and 1.45, respectively, outperforming broilers in G1, G2, G3, G5, and G6.

Over the entire experimental period (days 1–42), significant differences (P ≤ 0.05) were observed. Broilers in G3 and G4 achieved the most favorable cumulative FCR values of 1.47 and 1.45, respectively. These results were significantly better than those of G1 (1.63), G2 (1.67), and G6 (1.65), indicating that both curcumin and nano-curcumin supplementation improved feed efficiency, especially in the absence of lead acetate.

Oxidation Status

The results presented in Figure 1 illustrate the effect of curcumin and nano-curcumin supplementation on malondialdehyde (MDA) concentration in the liver. A significant increase (P ≤ 0.05) in MDA levels was observed in Group 2 (G2), which received lead acetate at 600 mg/kg feed, recording the highest value at 0.142. This was followed by Groups 1 (G1; control), 5 (G5; curcumin + lead acetate), and 6 (G6; nano-curcumin + lead acetate), which showed no significant differences among themselves and recorded MDA values of 0.095, 0.091, and 0.089, respectively. In contrast, the lowest MDA concentrations were observed in Group 3 (G3; curcumin 800 mg/kg) and Group 4 (G4; nano-curcumin 800 mg/kg), with values of 0.056 and 0.052, respectively, both significantly lower than all other groups (P ≤ 0.05).

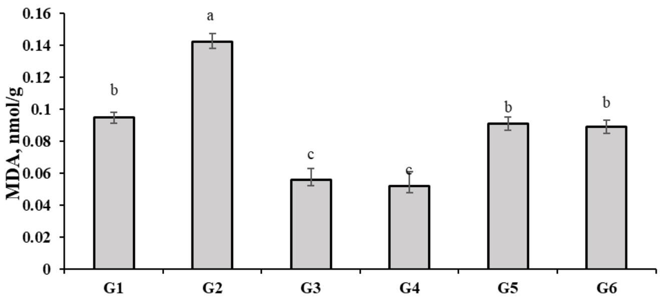

Figure 1: Impact of supplementation of curcumin and nano-curcumin to broiler´s diets contaminated with lead acetate on MDA in liver (mean± SE). G1: Control Group, G2: supplemented with lead acetate 600 mg kg^{-1} feed, G3: supplemented with curcumin 800mg kg^{-1} feed, G4: supplemented with nano-curcumin800mg kg^{-1} feed, G5: supplemented with curcumin 800mg kg^{-1} feed + lead acetate 600mg kg^{-1} feed, G6: supplemented with nano-curcumin800mg kg^{-1} feed + lead acetate 600mg kg^{-1} feed.

Figure 2 presents the results for glutathione peroxidase (GSH-Px) activity in the liver. Groups G3 and G4 exhibited the highest enzyme activities, recording values of 11.11 and 11.32, respectively, which were significantly higher than those in all other groups. Groups G5 and G6 recorded intermediate values of 8.44 and 8.95, respectively, which were statistically similar to the control group (G1; 8.72). The lowest GSH-Px activity was found in Group 2 (G2), with a value of 2.25, which was significantly lower (P ≤ 0.05) than all other groups.

Regarding oxidative stress indicators—free fatty acids (FFA) and peroxide value (PV)—as shown in Figures 3 and 4, Groups G3 and G4 (curcumin and nano-curcumin supplementation) recorded the most favorable values, indicating improved oxidative status. These were followed by Groups G5 and G6 (curcumin or nano-curcumin with lead acetate), which also showed significantly improved values compared to the control (G1). Group G2, which received lead acetate only, recorded the poorest values for both FFA and PV, confirming the oxidative damage induced by lead acetate in broiler liver tissue.

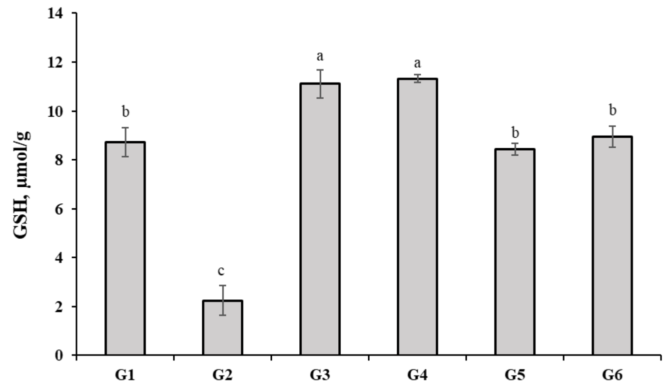

Figure 2: Impact of supplementation of curcumin and nano-curcumin to broiler´s diets contaminated with lead acetate on GSH in liver (± SE). G1: Control Group, G2: supplemented with lead acetate 600 mg kg^{-1} feed, G3: supplemented with curcumin 800mg kg^{-1} feed, G4: supplemented with nano-curcumin800mg kg^{-1} feed, G5: supplemented with curcumin 800mg kg^{-1} feed + lead acetate 600mg kg^{-1} feed, G6: supplemented with nano-curcumin800mg kg^{-1} feed + lead acetate 600mg kg^{-1} feed.

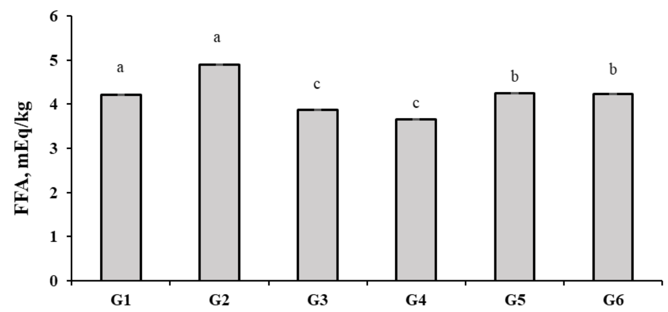

Figure 3: Impact of supplementation of curcumin and nano-curcumin to broiler´s diets contaminated with lead acetate on free fatty acids (FFA) in liver (± SE). G1: Control Group, G2: supplemented with lead acetate 600 mg kg^{-1} feed, G3: supplemented with curcumin 800mg kg^{-1} feed, G4: supplemented with nano-curcumin800mg kg^{-1} feed, G5: supplemented with curcumin 800mg kg^{-1} feed + lead acetate 600mg kg^{-1} feed, G6: supplemented with nano-curcumin800mg kg^{-1} feed + lead acetate 600mg kg^{-1} feed.

DISCUSSION

The results demonstrated that production performance traits, including body weight (BW), body weight gain (BWG), and feed conversion ratio (FCR), were improved in broilers fed diets containing curcumin at 800 mg/kg feed compared to those in the control group (G1) and the group fed lead acetate-contaminated diets (G2). This improvement may be attributed to the bioactive properties of curcumin, particularly its antioxidant effects, which help to mitigate oxidative stress in broilers (Rathore *et al*., 2020). Curcumin also plays a role in stimulating protein synthesis through the activation of enzymatic systems (Yousif *et al*., 2021), in addition to its known antibacterial and anti-inflammatory properties (Osman *et al*., 2017), which contribute to enhanced health and productivity.

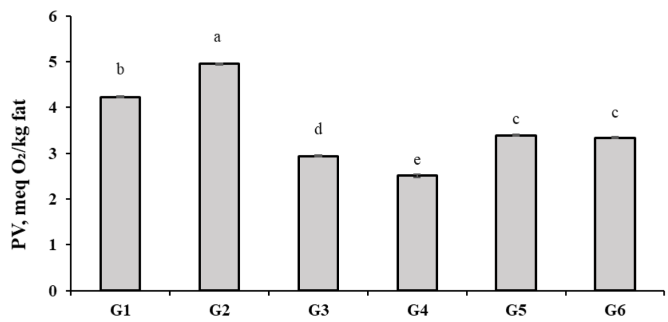

Figure 4: Impact of supplementation of curcumin and nano-curcumin to broiler´s diets contaminated with lead acetate on Peroxide Value (PV)äÂĄin liver (± SE). G1: Control Group, G2: supplemented with lead acetate 600 mg kg^{-1} feed, G3: supplemented with curcumin 800mg kg^{-1} feed, G4: supplemented with nano-curcumin800mg kg^{-1} feed, G5: supplemented with curcumin 800mg kg^{-1} feed + lead acetate 600mg kg^{-1} feed, G6: supplemented with nano-curcumin800mg kg^{-1} feed + lead acetate 600mg kg^{-1} feed.

Moreover, the enhanced performance observed with curcumin supplementation may be linked to its positive effects on gut morphology and microbiota. Curcumin has been reported to promote the growth of beneficial bacteria such as *Lactobacillus*, and to increase the length and density of intestinal villi. These changes enhance nutrient absorption and feed utilization by improving digestion and the metabolic efficiency of energy extraction from feed (Mousa *et al*., 2019). Furthermore, curcumin may enhance feed palatability, thereby increasing feed intake and overall nutritional benefit.

Herbal and natural feed additives, including curcumin, are also known to possess anti-mycotoxin properties. For instance, curcumin has been shown to counteract the effects of aflatoxin B1, produced by *Aspergillus parasiticus*, by acting directly on the causative agent and thus improving feed efficiency (Mousa *et al*., 2018b; Alhamdani *et al*., 2025). Additionally, curcumin stimulates the secretion of digestive enzymes such as pancreatic lipase and protein-synthesizing enzymes, further supporting improved feed metabolism and nutrient absorption (Fathy Abd-Ellatef *et al*., 2020; Moniruzzaman and Min, 2020).

However, it is worth noting that the findings of this study are in contrast with those of Rahmani *et al*. (2017), who reported no significant improvement in broiler performance following curcumin or nano-curcumin supplementation. This discrepancy may be due to differences in dosage, experimental design, broiler strain, or other environmental factors.

Lead acetate can disrupt cell membranes, causing a disturbance in the normal permeability of cellular envelopes and leading to enzyme degradation. The processes dependent on these enzymes become slower or may cease entirely, resulting in cell death (Surai and Fisinin, 2016). Additionally, lead acetate causes a significant increase in the level of nitric oxide (NO), which promotes the formation of reactive oxygen species (ROS). This process leads to an increase in the formation of free radicals and the oxidation of unsaturated fatty acids in cell membranes, which may result in a decline in mitochondrial function or a decrease in cellular energy (Shalan, 2025). The addition of curcumin or nano-curcumin to the diets of broiler chickens, or its combination with lead acetate, has improved antioxidant levels by enhancing the role of antioxidant enzymes or reducing oxidative stress within the cells. This is evident from measurements of the enzyme GSH-PX, and the reduction in lipid peroxidation is reflected in the significant decrease in MDA values in the liver of the broilers. The results are consistent with those of Badria *et al*. (2015), who noted a reduction in MDA concentration with the addition of curcumin to the diet compared to the treatment exposed to oxidative stress. The researcher pointed out the role of curcumin in mitigating oxidative stress by preserving unsaturated fatty acids from oxidation and attacks by free radicals such as reactive oxygen species (ROS).

The addition of lead acetate as an oxidizing agent to the feed led to a deterioration of antioxidant activity within the cells, which is evident in the Group values associated with lead acetate addition. An increase in MDA concentration in the liver of broilers accompanied this significant decrease in the group. This deterioration may be attributed to oxidative stress caused by the addition of lead acetate, which initiated a series of chemical reactions that ultimately resulted in internal oxidative stress by increasing oxygen production in the body's cells. This leads to an excessive retention of oxygen in blood, resulting in an overproduction of reactive oxygen species (Javorac *et al*., 2021). This increase is countered by a reduction in the antioxidant defense system, leading to a state of oxidative imbalance (Antonio-García and Masso-Gonzalez, 2008). Additionally, it could be due to the direct inhibitory effect of free radicals generated from oxidation processes induced by lead acetate on glutathione peroxidase, an enzyme responsible for scavenging free radicals within cells (Narayanankutty *et al*., 2019).

CONCLUSIONS AND RECOMMENFATIONS

Although curcumin and nano-curcumin supplementation did not have a significant direct effect on output traits, their inclusion in broiler diets effectively reduced oxidative stress induced by lead acetate and mitigated its harmful effects. This indicates that while these supplements may not independently enhance productive parameters under normal conditions, they play a protective role against environmental toxins such as lead acetate. As a result, curcumin and nano-curcumin contribute to the maintenance of broiler health and support improved overall productivity in the presence of oxidative stressors.

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NOVELTY STATEMENT

The novelty of our study lies in providing strong evidence that dietary supplementation with nano-curcumin in laying hens can effectively enhance overall productivity and mitigate the toxic effects of lead acetate. Notably, this study is among the first to demonstrate that nano-curcumin not only supports performance and health in lead-exposed hens but also contributes to improved food quality and safety, highlighting its potential as a functional feed additive in poultry production.

AUTHOR'S CONTRIBUTIONS

Safaa S. Hussein: Conceptualization, investigation, supervision, and validation. Baraa H. Mousa: Formal analysis, methodology, investigation, writing – original draft. Husam H. Nafea: Data curation and investigation. Tahreer M. Al-Thuwaini: Conceptualization and investigation.

Conflict of Interest

None.

REFERENCES

Abbas NK, Ali NA (2019). Effect of adding different levels of nano-boron particles to the diet in some of the productive traits for the broiler chicken (Ross 308). Plant Arch., 19(2):3446-3452.

Alhamdani HA, Shahooth MA, Ali NA, Mousa BH, Al-Thuwaini TM (2025). Individual and synergistic effect of adding zeolite and yeast to reduce the negative impact of aflatoxin b1 on the physiological and immune performance of laying hens. J. Anim. Health Prod., 13(1): 38-44. https://doi.org/10.17582/journal.jahp/2025/13.1.38.44

AL-Thuwaini TM, Ali NA, Ajafar MH (2022). Nanoparticles in Feed: a Potential Approach for Mitigating Heat Stress on Broilers. Rev. Agric. Sci., 10: 328–336. https://doi.org/10.7831/ras.10.0_328

Al-Zalzal AH, Ali EA (2024). Effect of Adding Fruit Powder (*Brassica oleracea L.*) to the Diet of Broiler Breeder Males on Some Biochemical and Reproductive Traits. IOP Conf. Ser. Earth Environ. Sci., 1371: 072019. https://doi.org/10.1088/1755-1315/1371/7/072019

Antonio-García MT, Massó-Gonzalez EL (2008). Toxic effects of perinatal lead exposure on the brain of rats: involvement of oxidative stress and the beneficial role of antioxidants. Food Chem. Toxicol., 46 (6): 2089–2095. https://doi.org/10.1016/j.fct.2008.01.053

Badria FA, Ibrahim AS, Badria AF, Elmarakby AA (2015). Curcumin Attenuates Iron Accumulation and Oxidative Stress in the Liver and Spleen of Chronic Iron-Overloaded Rats. PLoS one, 10(7): e0134156. https://doi.org/10.1371/journal.pone.0134156

Egan H, Kirk RS, Sawyer R (1981). Pearson's chemical analysis of foods. Edinburgh, UK, Churchill Livingstone.

El-Damrawy SZ, Mariey YA, El-far MK, Abouzeid A (2024). Effect of Curcumin as A Natural Feed Additive on Productive Performance and Immune Response of Broiler Chicks. J. Sustainable Agric. Environ. Sci., (JSAES), 3(2): 34-44. https://doi.org/10.21608/jsaes.2024.275218.1082

Farhan OM, Mousa BH, AlHamdani AA (2019). Effects of dietary L-carnitine to diets with different fat sources on productive performance of broiler. Plant Arch., 19(2): 4409–4414.

Fathy Abd-Ellatef GE, Gazzano E, Chirio D, Ragab Hamed A, Belisario DC, Zuddas C, Peira E, Rolando B, Kopecka J, Assem Said Marie M, Sapino S (2020). Curcumin-Loaded Solid Lipid Nanoparticles Bypass P-Glycoprotein Mediated Doxorubicin Resistance in Triple Negative Breast Cancer Cells. Pharmaceutics, 12: 96. https://doi.org/10.3390/pharmaceutics12020096

Fesseha H, Degu T, Getachew Y (2020). Nanotechnology and its application in animal production: A review. Vet. Med. Open J., 5(2): 43-50. https://doi.org/10.17140/VMOJ-5-148

Hammod AJ, Abd El-Aziz AH, Areaaer AH, Alfertosi KA (2020). Effect of Dill Powder (*Anethum graveolens*) as a Dietary Supplement on Productive Performance, Mortality and Economic Figure in Broiler. Earth Environ. Sci., 553 (1): 012018. https://doi.org/10.1088/1755-1315/553/1/012018

Hasan SM, Abou-Rawash AE, Bekheet MS (2016). Protective Role of an Aqueous Extract of punica Granatum (Pomegranate) Peel on Lead-Induced Anemia In Rats. Alexandr J. Vet. Sci., 50(1): 45. https://doi.org/10.5455/ajvs.228349

Hameed A, Mousa BH (2025). Role of Bioactive Lycopene in Mitigating the Impact of Aflatoxin B1 on Physiological Performance of Bbroiler Chickens. Egypt J. Vet. Sci., 56(7): 1489–1497.

Jaber AS, Ali EA (2023). The Influence of Feeding a *Moringa Oleifera* Leaf Aqueous Extract on the Biochemical Attributes of the Lohmann Brown Rooster Breed. IOP Conf. Ser. Earth Environ. Sci., 1262: 072037. https://doi.org/10.1088/1755-1315/1262/7/072037

Javorac D, Antonijević B, Anđelković M, Repić A, Bulat P, Djordjevic AB, Baralić K, Đukić-Ćosić D, Antonić T, Bulat Z (2021). Oxidative stress, metallomics and blood toxicity after subacute low-level lead exposure in Wistar rats: benchmark dose analyses. Environ. Pollut., 291: 118103. https://doi.org/10.1016/j.envpol.2021.118103

Kim JH, Park GH, Han GP, Choi HS, Ji SY, Kil Y (2020). Prediction of lead intake and tissue lead concentrations in broiler chickens using feather lead concentrations. Biol. Trace Elem. Res., 193(2):517-23. https://doi.org/10.1007/s12011-019-01726-2

Khanam F, Iqbal MN, Ashraf A, Alam S, Muhammad A, Xiao S, Toor S, Mumtaz H (2016). Evaluation of Changes in Liver Enzymes in Broiler Chicks (Gallous domesticus). PSM Veter. Res., 211(1):26-31.

Mahde MH, Hammod AJ (2024). Effect of Addition Aqueous Extract of Camel Thorn (*Alhagi maurorum*) Plant Roots and Some of Immune Enhancers with Drinking Water on Productive Performance of Broilers. Earth Environ. Sci., 1371: 072008. https://doi.org/10.1088/1755-1315/1371/7/072008

Mohammadi V, Ghazanfari S, Mohammadi-Sangcheshmeh A, Nazaran MH (2015). Comparative effects of zinc-nano complexes, zinc-sulphate and zinc methionine on performance in broiler chickens. Br. Poult. Sci., 56: 486–493 https://doi.org/10.1080/00071668.2015.1064093.

Moniruzzaman M, Min T (2020). Curcumin, curcumin nanoparticles and curcumin nanospheres: A review on their pharmacodynamics based on monogastric farm animal, poultry and fish nutrition. Pharmaceutics, 12: 447. https://doi.org/10.3390/pharmaceutics12050447

Mousa BH, Abdulateef SM, Alhamdani HA, Alhayani NN, Alhamdani AA, Nafea HH (2020). Effect of Dietary Natural Feed Additives to Minimize Negative Role of Peroxide Hydrogen in Broiler. Biochem. Cell. Arch., 20(2): 5223-5230.

Mousa BH, Awad AM, Alhamdani HA, Nafea HH, Alhamdani AA (2019). Inclusion of garlic (*Allium Sativum.*) and turmeric (*Curcuma longa L.*) powder to laying hens' diets on egg quality traits, bacterial population and intestinal histomorphology. Ann. Trop. Med. Public Health, 22(12): S373. https://doi.org/10.36295/ASRO.2019.221224

Mousa BH, Nafa HH, Al-Rawi YT, Al-Dulaimy RK (2018a). Effect of partial substitution of crude glycerol as an alternative energy source to diets in productive performance and some blood parameters of broiler. J. Pharm. Sci. Res., 10(11): 2907-2911.

Mousa BH, Nafaa HH, Attallah OK (2018b). Comparison of adding locally prepared probiotic and organic acid (acetic acid) to diets and effects on performance of laying hens. Biochem. Cell. Arch., 18: 1245-1249.

Naicker N, De Jager P, Naidoo S, Mathee A (2018). Is there a relationship between lead exposure and aggressive behavior in shooters?. Int. J. Environ. Res. Public Health, 15(7):1427 https://doi.org/10.3390/ijerph15071427.

Narayanankutty A, Job JT, Narayanankutty V (2019). Glutathione, an antioxidant tripeptide: dual roles in carcinogenesis and chemoprevention, Curr. Protein Pept. Sci., 20 (9): 907–917. https://doi.org/10.2174/1389203720666190206130003

NRC (1994). Nutrient Requirements of Poultry. 9th rev. *ed*. Nath. Acad. Press, Washington, DC.

Offor SJ, Mbagwu HO, Orisakwe OE (2017). Lead induced hepato-renal damage in male albino rats and effects of activated charcoal. Front Pharmacol., 14 (8):107. https://doi.org/10.3389/fphar.2017.00107

Osman AH, El-Far AH, Sadek KM, Abo-Ghanema II, Abdel-Latif MA (2017). Immunity, Antioxidant Status, and Performance of Broiler Chickens Fed Turmeric (*Curcuma Longa*) Rhizome Powder. Alex. J. Vet. Sci., 54 (2): 19-28. https://doi.org/10.5455/ajvs.272232

Rahman S, Joshi MV (2009). Effect of Lead Toxicity on Growth and Performance of Broilers. Tamilnadu J. Vet. Anim. Sci., 5 (2): 59-62.

Rahmani M, Golian A, Kermanshahi H, Bassami MR (2017). Effects of curcumin and nanocurcumin on growth performance, blood gas indices and ascites mortalities of broiler chickens reared under normal and cold stress conditions. Ital. J. Anim. Sci., 16(3):438-46. https://doi.org/10.1080/1828051X.2017.1290510

Rathore S, Mukim M, Sharma P, Devi S, Nagar JC, Khalid M (2020). Curcumin: A Review for Health Benefits. Int. J. Res. Rev, 7(1): 273-290.

SAS (2001). Institute SAS/STAT User's Guide for Personal Computer. Relesse 6.12 SAS Institute, Inc., Cary, N.C., USA.

Shakir AR, Ali EA (2024). Effect of Dosing Different Levels of Nano-Curcumin on Some Histological Traits of Testicles of Broiler Breeders Cocks. Eur. J. Theor. Appl. Sci., 2(4): 148-153. https://doi.org/10.59324/ejtas.2024.2(4).12

Shalan MG (2025). Mitigating lead acetate-induced histopathologic and physiologic disorders in rats receiving vitamin C and glutathione supplement. Heliyon, 11(1): e41256. https://doi.org/10.1016/j.heliyon.2024.e41256

Song Z, Feng R, Sun M, Guo C, Gao Y, Li L, Zhai G (2011). Curcumin-loaded PLGA-PEGPLGA triblock copolymeric micelles: preparation, pharmacokinetics and distribution in vivo. J. Colloid Interface Sci., 354(1): 116-123. https://doi.org/10.1016/j.jcis.2010.10.024

Surai PF, Fisinin VI (2016). Natural antioxidants and stresses in poultry production: from vitamins to vitagenes. XXV World's Poult. Congr., 116-121.

Wani AL, Ara A, Usmani JA (2015). Lead toxicity: A review. Interdiscip Toxicol., 8(2):55-64. https://doi.org/10.1515/intox-2015-0009

Wheeler QD, Nixon KC (1990). Another way of looking at the species problem: a reply to de Queiroz and Donoghue. Cladistics, 6: 77-81. https://doi.org/10.1111/j.1096-0031.1990.tb00526.x

Witte VC, Krause GF, Bailey ME (1970). A new extraction method for determining 2-thiobarbituric acid values of pork and beef during storage. J. Food Sci., 35: 582-585. https://doi.org/10.1111/j.1365-2621.1970.tb04815.x

Yadav D, Neeraj K (2014). Nanonization of Curcumin by Anti-Solvent Precipitation: Process Development, Characterization, Freeze Drying and Stability Performance. Int. J. Pharm., 477: 564-577. https://doi.org/10.1016/j.ijpharm.2014.10.070

Yousif SI, Al-Hamdani WA, Mousa BH, Al-Hamdani AA (2021). Effect Using Wheat Triticum aestivum and Corn Zea mays in Broiler Diets and Sex on Specific Characteristics. Earth Environ. Sci., 761(1): 012126. https://doi.org/10.1088/1755-1315/761/1/012126