



EFFECT OF LEMON PEEL EXTRACT IN DRINKING WATER IN PERFORMANCE, AND PHYSIOLOGICAL PARAMETERS BROILER CHICKEN

Oday Khalaf Hamad

Department of Animal Production, College of Agriculture, Tikrit University, Iraq

oday_alnasser@tu.edu.iq

Abstract: In this study, we have studied the effect of lemon peel glycerite extract through drinking water on growth and antioxidant status of broiler chickens. We randomly assigned 180 broiler chicks to four treatments, with 45 birds per treatment, three replicates per treatment and 15 birds per replicate. The control group was given plain drinking water, while L1, L2 and L3 got lemon peel glycerite extract at 0.5, 1.0 and 1.5 mL/L, respectively. We measured growth and antioxidant status using body weight (body weight gain), feed intake and feed conversion ratio. L1 and L2 treatments improved body weight and body weight gain overall in the last body weight gain and overall feed conversion ratio of L1 improved. The total feed intake was not significantly affected. Lemon peel supplements also reduced MDA and enhanced SOD activity, while GSH showed a non-linear response between treatments. These results suggest that mild supplementation with lemon peel glycerite extract, especially for 0.5-1.0 mL/L, can enhance broiler growth efficiency and antioxidant status.

Keywords: Broiler chickens, Lemon peel extract, Glycerite extract, Growth performance, Feed conversion ratio, Phytogenic additives.

Introduction

Today's broiler production presents birds with environmental and metabolic stressors such as rapid growth, high stocking density, seasonal heat load, transport and handling. These stressors can increase oxidative pressure and activation of physiological stress pathways, which may impair growth efficiency, feed efficiency, immune capability and physiological stability. Broilers with chronic stress are also known to experience changes in commonly used stress indicators including the ratio of heterophil to lymphocytes and circulating corticosterone (Bilal et al., 2021; Yu et al., 2021). As stress can affect production efficiency and economic growth, increasing attention has been on low-cost, practical phytogetic interventions that can be administered easily through drinking water without altering feed formulation. This has been motivated by the fact that lemon peel (*Citrus limon*) has been identified as one of the most effective compounds since it is inexpensive, readily available and full of biologically active compounds. Lemon peel contains a high amount of phenolic compounds such as hesperidin and flavanone glycosides, and essential oil such as limonene. As far as we know, citrus peels are concentrated sources of polyphenols and flavonoids with an antioxidant potential (Rafiq et al., 2018). Such bioactive compounds could contribute to oxidative balance by scavenging reactive oxygen species and supporting endogenous antioxidant defense mechanisms (e.g., superoxide dismutase, glutathione-related defenses and other cellular antioxidant mechanisms). The experimental studies in broiler chickens support the benefit of citrus-based additives. Akbarian et al. (2013) reported that citrus peel extract had an impact on broilers' growth performance and biochemical status, and intestinal structure. In another study, lemon and orange peel extract had an effect on antioxidant enzyme activity, plasma hormone levels, and serum metabolite levels in heat stressed broilers. More specifically, Ahmed and Mustafa (2025) measured lemon peel glycerite extract in drinking water and found improvements in several productive and physiological characteristics, and the most favorable responses were obtained at moderate levels of supplementation. In this way, lemon peel extract could be a practical natural phytogetic beverage for the broiler to benefit in terms of its antioxidant activity and its physiology. However, the response to supplementation seems to depend on dose and excessive inclusion may not provide additional benefits. Therefore, the evaluation of different concentrations is necessary to identify an effective range of supplementation in broiler production conditions. Thus, we conducted the present study over the course of 35 days for the assessment of the effect of lemon peel glycerite extract in drinking water on growth and antioxidant status of broiler chickens. Productive responses were measured by body weight, body weight gain, food intake and feed conversion ratio, antioxidant status was assessed by reduced glutathione (GSH), superoxide dismutase (SOD) and malondialdehyde (MDA).

Materials and Methods

1. Ethical approval

All experimental procedures with live animals were carried out in accordance with the institutional and ethical standards of the study. The study protocol was approved by the Animal Ethics Committee of the College of Agriculture, Tikrit University before the beginning of the experiment and the approval number and date were registered (Approval No. [], dated []); and all work with birds (handling birds daily, blood sampling, and euthanasia when necessary for final sample collection) followed

humane care guidelines that were established by the committee in their study. These were implemented to protect birds and not to inflict pain, stress, and distress.

2. Housing, birds, and general management

A total of 180 one-day-old Ross 308 broiler chicks from a single hatchery batch, to limit genetic and maternal age variation, were used in a 35-day trial. The chicks were randomly placed in four different experimental treatments, with 45 birds per treatment. Each treatment consisted of three replicates, with 15 birds per replicate. Chicks will be weighed at the point of placement to get a correct initial body weight, and this weight will be used to distribute the birds equally in each of the pens (balanced allocation) so that the starting body weight does not affect the treatment comparisons. Birds will be kept in floor pens on fresh wood-shaving litter and the stocking density is the same in all pens, so that stocking density is not altered. Only drinking water treatment will be different for all pens. Brooding temperature is in accordance with standard Ross 308 guidelines and will be adjusted according to bird age. Feed and water will be available for ad libitum consumption throughout the 35-day period. Feeder and drinker space per bird will be equal in each pen. Diets will be prepared in three stages, starter, grower and finisher, to match or exceed the nutritional requirements of Ross 308 broilers (NRC, 1994). All treatment groups will receive the same basal diet formulation so that the nutrient composition of the diet is not a determining factor in the difference in treatment groups and only drinking-water content will be different. The temperature, relative humidity, and ventilation rate will be recorded across the house (or at least at fixed daily times) so that the thermal environment can be measured and evaluated for performance and as a covariate.

3. Experimental design and treatment structure

The trial will follow a completely randomized design with a single factor: drinking water treatment at four levels. Pens will be assigned to treatments at random, and each treatment will be replicated across multiple pens to allow the pen (not individual bird) to serve as the experimental unit for statistical analysis, which is standard practice for floor-pen broiler trials because birds within the same pen share feeder, drinker, and litter conditions and are therefore not statistically independent of one another.

Drinking-water groups:

Group-C: Control (plain drinking water, no additive). Group-L1: Lemon peel glycerite extract, 0.5 mL/L drinking water. Group-L2: Lemon peel glycerite extract, 1 mL/L drinking water. Group-L3: Lemon peel glycerite extract, 1.5 mL/L drinking water.

Water additives will be freshly prepared and the drinking water changed daily (or more frequently if required for stability of ascorbic acid, which degrades with time, light, and temperature exposure) to maintain the intended concentration throughout each day of the trial.

4. Preparation of the lemon peel glycerite extract

The lemon peel glycerite will be prepared according to Ahmed and Mustafa's (2025) recipe. Fresh lemon peels will be washed, cleaned of adhering pulp and cut into small pieces. About 500 g of prepared peel will be placed in a glass container with 250 mL of warm water and 750 mL of 98% glycerin and stored in a cool, dark environment for 2–4 weeks to extract the phenolic and flavonoid components into the glycerin-water matrix. At the end of the extraction process, the mixture will be filtered to remove the solid peel and the finished glycerite will be stored under the conditions used (cool, dark, sealed) to preserve its bioactivity. The extract will be dosed into drinking water at 2 mL/L, which is within the 1–3 mL/L level that Ahmed and Mustafa

(2025) found to be associated with the best performance and physiological response in heat-stressed broilers.

5 Productive performance measurements

Productive performance will be recorded on a weekly basis throughout the 35-day trial. Pen-level body weight will be recorded at placement and at the end of each week to calculate body weight gain; feed offered and feed refused will be weighed weekly, by pen, to calculate feed intake; feed conversion ratio will be calculated as cumulative feed intake divided by cumulative body weight gain for each pen and week; No mortality was recorded in any of the experimental groups throughout the 35-day trial, indicating that all supplementation levels were well tolerated by the broiler chickens under the conditions of the present study.

6 Oxidative Stress and Antioxidant Parameters

At the end of the experiment, blood samples were collected from a representative sample of broiler chickens in each group. The blood was taken by venipuncture of the wing vein, with a standard procedure to minimize stress and to produce consistent samples. The blood was left at room temperature, and centrifugation separated the blood samples into clean tubes and stored under suitable frozen conditions until analysis to ensure the stable levels of the biomarkers.

The antioxidant capacity and oxidative stress level of birds were evaluated by measuring three serum biomarkers: reduced glutathione (GSH), superoxide dismutase (SOD), and malondialdehyde (MDA). GSH and SOD were measured as signs of the endogenous antioxidant defense system, reflecting the bird's ability to neutralize reactive oxygen species and limit cellular damage. MDA, a major end product of lipid peroxidation, was measured as an indicator of oxidative damage to cell membranes and lipids.

All parameters were determined using commercially available assay kits following the manufacturers' instructions. Absorbance was read spectrophotometrically at the wavelength required for each assay, and the results were expressed in the units recommended by the kit manufacturers.

7. Statistical analysis

Data will be analyzed as a one-way analysis of variance (ANOVA) with drinking-water treatment as the single fixed factor. Pen will be treated as the experimental unit for productive performance variables. Where the ANOVA indicates a significant treatment effect, means will be separated using an appropriate multiple-comparison procedure (Duncan test), and statistical significance will be declared at $P < 0.05$. Mortality data, which are typically non-normally distributed, will be analyzed using a method appropriate for count or proportion data.

Result and Discussion

1. Body Weight

The results presented in Table 1 showed that supplementation of drinking water with lemon peel glycerite extract significantly affected broiler body weight at several stages of the experimental period ($P \leq 0.05$). During the first week, the intermediate supplementation level (L2) resulted in significantly higher body weight than the control and L1 treatments, whereas L3 showed an intermediate response. At 14 days, L2 showed a significant reduction compared with the other treatments, while no significant differences were detected among treatments at 21 days. Table 1. During the later growth period, the positive effect of supplementation became more evident. At 28 days, all lemon peel-treated groups showed higher body weight than the control,

with L3 showing the greatest response. By 35 days, however, L1 and L2 had significantly greater final body weight than both the control and L3 treatments. Table 1 These findings suggest that the response to lemon peel glycerite was dose-dependent and that moderate concentrations were more effective than the highest concentration.

Table 1. Effect of Lemon Peel Extract in Drinking Water on Body Weight of Broiler Chickens

Groups	Age (day)				
	7	14	21	28	35
Control	149.10±0.49 ^b	520.88±8.39 ^a	1051.11±30.87 ^a	1619.55±8.91 ^c	2212.89±15.67 ^b
Group-L1	144.32±1.20 ^b	525.66±3.83 ^a	1027.11±24.88 ^a	1647.88±7.77 ^b	2273.33±13.86 ^a
Group-L2	153.33±0.69 ^a	490.77±1.96 ^b	1064.22±1.74 ^a	1665.44±1.34 ^{ab}	2291.67±7.88 ^a
Group-L3	148.33±2.88 ^{ab}	515.57±1.61 ^a	1065.11±0.96 ^a	167166±2.88 ^a	2207.33±8.82 ^b

Means within the same row bearing different superscript letters (a, b, c) are significantly different at $P \leq 0.05$, whereas means bearing the same letter are not significantly different. Values are expressed as mean $\pm$ standard error (SE)

Group L1, 2, and 3: add Lemon peel glycerite extract, 0.5, 1, and 1.5 mL/L drinking water

The present findings are supported by Oluremi et al. (2014), who investigated *Citrus sinensis* peel extract in broiler diets. The authors reported that supplementation with 1000 ppm for the first 21 days increased final body weight from 2426.3 g in control birds to 2692.5 g, representing an improvement of approximately 11% ($P < 0.05$). This response agrees with the improvement in final body weight observed at the moderate supplementation levels in the present study. Similarly, Seidavi et al. (2015) evaluated *Citrus sinensis* peel extract at 1000 or 1250 ppm in drinking water and reported improved weight gain during the 22–42-day period, together with better feed conversion efficiency. These findings support the concept that citrus-derived phytochemicals may exert their clearest growth-promoting effects during the grower and finisher periods. In contrast, Akbarian et al. (2013) reported that dietary lemon peel extract at 200 and 400 mg/kg feed did not significantly improve broiler growth performance under heat stress. Their birds were exposed to 34°C for 5 h daily from day 28 to day 38, which may explain the difference from the present results. Differences in extract type, administration route, dose, age of birds, and environmental conditions may therefore account for the variable responses among studies.

2. Body Weight Gain

Body weight gain was significantly influenced by lemon peel extract during several experimental periods. During the first week, L2 produced greater weight gain than L1, while during the second week L1, L3 and the control performed better than L2. During the third week, L2 again showed the greatest response, while during the fourth week L1 achieved the highest weight gain. Table 2. During the final week, L1 and L2 produced significantly greater gains than L3. More importantly, cumulative body weight gain from 7 to 35 days was significantly higher in L1 and L2 than in the control and L3 groups. Table 2 This demonstrates that the beneficial effect was more apparent when overall rather than weekly growth performance was considered.

Table 2. Effect of Lemon Peel Extract in Drinking Water on Body Weight Gain of Broiler Chickens

Age (day)	Groups			
	Control	Group-L1	Group-L2	Group-L3
7	106.47±0.29 ^{ab}	104.74±0.94 ^b	110.08±0.16 ^a	106.52±2.07 ^{ab}
14	371.67±7.59 ^a	382.00±5.73 ^a	337.44±1.61 ^b	367.24±7.73 ^a
21	529.78±22.34 ^{ab}	489.78±28.77 ^b	573.44±1.47 ^a	549.53±9.25 ^{ab}
28	568.44±22.13 ^b	643.55±19.95 ^a	600.22±3.85 ^{ab}	606.55±1.92 ^{ab}
35	593.33±22.40 ^a	621.11±2.32 ^a	627.89±9.73 ^a	535.67±6.01 ^b
7-35	2169.71±15.94 ^b	2241.20±5.97 ^a	2249.09±8.11 ^a	2165.52±8.04 ^b

Means within the same row bearing different superscript letters (a, b, c) are significantly different at $P \leq 0.05$, whereas means bearing the same letter are not significantly different. Values are expressed as mean $\pm$ standard error (SE)

Group L1, 2, and 3: add Lemon peel *glycerite* extract, 0.5, 1, and 1.5 mL/L drinking water

The improvement observed here is consistent with Seidavi et al. (2015) who found that supplementing with 1000 and 1250 ppm Citrus sinensis peel extract improved weight gain during the 22-42 day period. Like the present study, the citrus extract was provided by drinking water. The findings are also comparable with those of Oluremi et al. (2014), who found that taking 1000 ppm Citrus sinensis peel extract during the starter period increased the final broiler body weight from 2426.3 to 2692.5 g. While the use of orange peel and not lemon peel is more common in the citrus industry, the flavonoids in the citrus and phenolics in the drink can be used in contrast to the other fruits. On the other hand, Akbarian et al. (2013) found no improvements in growth performance after broilers received 200 or 400 mg/kg lemon peel extract during the finisher phase under chronic heat stress. This difference may be attributed to the shorter period of supplementation and the use of dietary supplementation rather than drinking water.

3. Feed Intake

Feed intake was also influenced differently by the treatments in each of the periods of growth. There was no significant difference in the first week. In the next weeks, the treatment difference was bigger and the direction of the response was different according to age. Table 3. Despite weekly differences, the total feed intake from 7 to 35 days did not vary significantly among the experimental groups. Table 1. So the improvement in weight gain in L1 and L2 is not simply due to feed consumption.

Table 3. Effect of Lemon Peel Extract in Drinking Water on Feed intake of Broiler Chickens

Age (day)	Groups			
	Control	Group-L1	Group-L2	Group-L3
7	122.33±3.92 ^a	119.81±3.43 ^a	122.00±0.57 ^a	118.66±0.33 ^a
14	432.66±5.92 ^{ab}	449.88±16.61 ^{ab}	420.65±2.90 ^b	473.61±17.80 ^a
21	756.77±3.84 ^b	749.88±1.92 ^b	803.33±19.53 ^a	749.22±4.89 ^b
28	1000.44±1.97 ^a	933.44±33.71 ^b	1004.44±17.46 ^a	930.21±15.40 ^b
35	1068.89±12.52 ^b	1076.44±5.77 ^{ab}	1140.66±7.72 ^b	1128.89±35.61 ^{ab}
7-35	3381.10±10.47 ^a	3329.46±16.33 ^a	3491.09±11.10 ^a	3400.60±13.18 ^a

Means within the same row bearing different superscript letters (a, b, c) are significantly different at $P \leq 0.05$, whereas means bearing the same letter are not significantly different. Values are expressed as mean $\pm$ standard error (SE)

Group L1, 2, and 3: add Lemon peel *glycerite* extract, 0.5, 1, and 1.5 mL/L drinking water

The present results are somewhat in line with those of Akbarian et al. (2013), who found that the dietary supplementation of lemon peel extract at 200 or 400 mg/kg did not significantly affect feed intake in finishing broilers reared under high ambient temperature. On the other hand, Seidavi et al. (2015) reported that the feed intake of citrus peel extract was subject to differences in both the level of the dose and the duration of the supplementation. The control birds ate about 1065.8 g/bird in the first 21 days of age and the birds with 1000 ppm for the entire 42 days ate just around 956.9 g/bird in the same early stage. Likewise, feed intake after the entire 1-42 day period changed based on the amount of supplementation and concentration used. These results show that citrus peel extracts can affect the level of feed consumption, but the extent and duration of exposure are determined by the dose and the time.

The cumulative feed intake was not significantly different between treatments, even though body weight gained. This trend suggests that supplemented birds used the nutrients they received more effectively, converting a similar amount of feed into greater weight gain. One possible explanation is that the phytochemicals in citrus peel have antioxidant and antimicrobial activity in the gastrointestinal tract and may curb oxidative stress and harmful microorganisms, promoting a favorable environment for digestion and nutrient absorption leading to better growth.

4. Feed Conversion Ratio

Feed conversion ratio showed significant treatment-related differences during several growth stages. No significant effect was observed during the first week. At 14 days, the control and L1 groups showed more favorable feed conversion than L3, whereas no differences were detected during the third week. Table 4. During the fourth week, L1 and L3 showed better feed conversion than the control. In contrast, during the final week the highest supplementation level, L3, resulted in poorer feed conversion than the other treatments. Over the entire 7–35-day period, L1 exhibited significantly better feed conversion than all other groups. Table 4.

Table 4. Effect of Lemon Peel Extract on Feed Conversion Ratio of Broiler Chickens

Age (day)	Groups			
	Control	Group-L1	Group-L2	Group-L3
7	1.14±0.03 ^a	1.14±0.02 ^a	1.10±0.01 ^a	1.11±0.02 ^a
14	1.16±0.01 ^b	1.17±0.06 ^b	1.24±0.01 ^{ab}	1.28±0.02 ^a
21	1.43±0.05 ^a	1.53±0.09 ^a	1.39±0.03 ^a	1.35±0.03 ^a
28	1.76±0.07 ^a	1.45±0.08 ^b	1.66±0.04 ^{ab}	1.52±0.02 ^b
35	1.80±0.06 ^b	1.72±0.10 ^b	1.81±0.04 ^b	2.10±0.04 ^a
7-35	1.55±0.01 ^a	1.48±0.02 ^b	1.54±0.10 ^a	1.56±0.02 ^a

Means within the same row bearing different superscript letters (a, b, c) are significantly different at $P \leq 0.05$, whereas means bearing the same letter are not significantly different. Values are expressed as mean ± standard error (SE)

Group L1, 2, and 3: add Lemon peel glycerite extract, 0.5, 1, and 1.5 mL/L drinking water

The improvement of overall FCR at the lowest supplementation level is in line with Seidavi et al. (2015) who found that drinking water with Citrus sinensis peel extract increased feed conversion during the 22-42 day period. In their study birds were fed 1000 or 1250 ppm, suggesting that Citrus peel-based compounds can increase feed utilization when used for drinking water. In the same way Oluremi et al. (2014) have shown that Citrus sinensis peel extract supplementation during the first

21 days reduced feed intake and feed conversion ratio significantly compared to the control treatment. Their results support the improved feed-use efficiency at the appropriate supplementation level in our experiment. On the other hand, Akbarian et al. (2013) did not find any positive effect in FCR when broilers were supplemented with 200 or 400 mg/kg lemon peel extract at high temperatures. Once again, these results suggest that lemon peel extract may be effective depending on the dose, extraction method, route of administration, time of supplementation and environmental stress.

5. Reduced Glutathione (GSH)

Lemon peel extract supplementation had a significant effect on serum GSH concentration ($P \leq 0.05$) in Fig. That is, the control group had the highest level and was significantly different from all the other supplemented groups. Of the lemon peel treatments, there is a higher GSH concentration in L3 than L1 and L2 when compared to L2 and the other treatments. The different superscript letters in the different treatment indicate significant differences between the groups. The GSH response indicates that this antioxidant effect of lemon peel extract is not linear and doesn't depend on the dose. The lower and intermediate concentrations reduced GSH compared to the control, while the higher supplementation level partially restored GSH concentration. This is likely related to the adaptive utilization and regeneration of reduced glutathione in response to citrus-based bioactive compounds rather than a simple increase in concentration. Citrus peels are full of flavonoids and phenolic compounds, ascorbic acid, and other antioxidant components which can influence the antioxidant systems in the system. Ebrahimi et al. (2019) showed that the addition of citrus waste in broiler diets significantly improved blood GSH from 8.18 $\mu\text{g/mL}$ in the control to 14.64 $\mu\text{g/mL}$ at 5% citrus waste supplementation ($P = 0.042$). This shows that citrus-based ingredients can affect glutathione antioxidant systems, but the level and extent of response depend on the level of citrus inclusion and type of citrus preparation. Further, a recent study of sweet orange peel meal (or a combination of both) found a significantly increased glutathione and antioxidant indices in supplemented broilers compared to untreated birds. The differences between the above findings and the present ones could be related to the glycerite lemon peel extract in drinking water and not dried citrus material in feed and the different dose, extraction method, age, and physiological state of the birds.

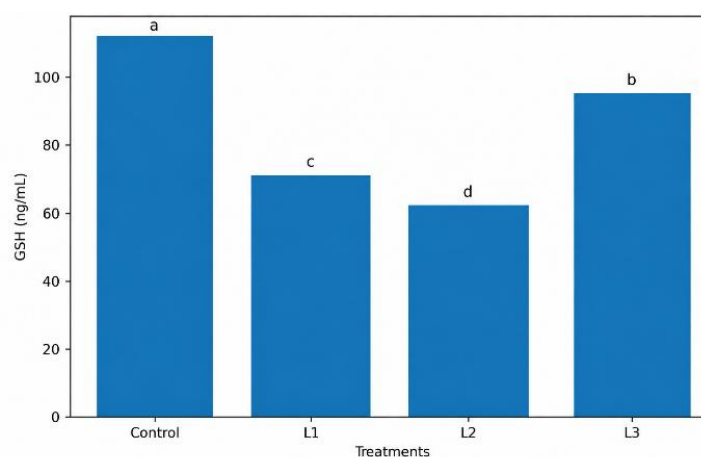


Figure 1. Effect of Lemon Peel Glycerite Extract Supplementation in Drinking Water on Serum Reduced Glutathione (GSH) Level in Broiler Chickens

Group L1, 2, and 3: add Lemon Peel Glycerite Extract, 0,5, 1, and 1,5 mL/L Drinking Water

6. Malondialdehyde (MDA)

Figure 2 has shown a considerable decrease in serum MDA after supplementing with lemon peel extract. The control group has shown a very high level of MDA relative to all the supplements ($P \leq 0.05$). L1 is significantly lower than control while L2 and L3 are also lower and not much different from each other. Therefore, lemon peel supplementation shows a clear protective effect against lipid peroxidation, with best response at intermediate and highest concentrations. MDA is a commonly used indicator of oxidative degradation of membrane lipids and the decrease in it indicates less lipid peroxidation and thus improved oxidative stability. The dramatic decrease in MDA in the supplemented groups may be due to the antioxidant components of lemon peel, such as flavonoids and phenolic compounds that can scavenge reactive oxygen species and disrupt lipid oxidation chains. The present result is in line with Zhang et al. (2016), who showed that supplementation with 80 mg/kg dried tangerine peel extract significantly reduced plasma MDA compared to the control ($P = 0.02$). The same study also showed that low levels of citrus peel extract also improved glutathione peroxidase activity and thus the antioxidant defense system was more robust. Similar findings were also reported by Ebrahimi et al. (2019), who found that the lipid peroxidation indices were significantly altered by dietary citrus waste supplementation in broilers. At moderate inclusion levels, lipid peroxidation levels were lower than in the untreated control. More recently, we have seen the sweet orange peel meal supplementation significantly lower MDA in broiler chickens and increase endogenous antioxidant indices.

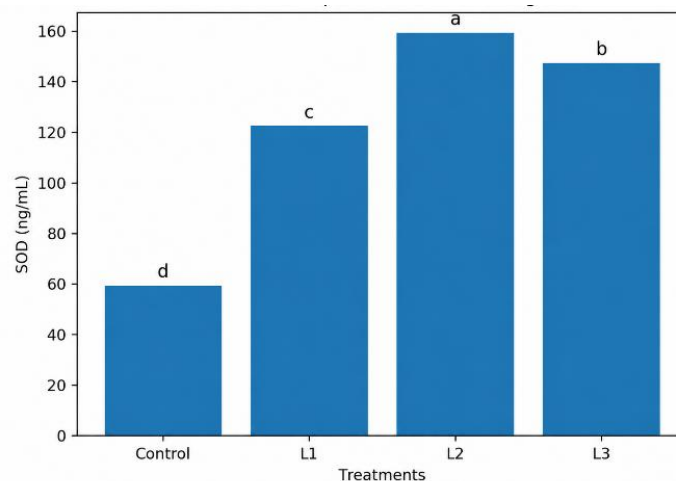


Figure 2. Effect of Lemon Peel Glycerite Extract Supplementation in Drinking Water on Serum Malondialdehyde (MDA) Level in Broiler Chickens
Group L1, 2, and 3: add Lemon Peel Glycerite Extract, 0,5, 1, and 1,5 mL/L Drinking Water

7. Superoxide Dismutase (SOD)

As can be seen from Figure 3, after L2 and L3 we saw an increase in serum SOD activity ($P \leq 0.05$). SOD activity in the control group was lowest and all these supplements were higher. L2 had the highest SOD activity and was very different from

the other groups (L3 and then L1). L2 dropped off significantly from L2 to L3 so that the antioxidant response reached its maximum at the intermediate (L2) level and not continued to grow. A higher SOD activity indicates that the enzyme-based antioxidant defense system is better. A decrease also suggests that the antioxidant levels had already been increased at the intermediate level of L2 and L3 but the antioxidant response was still very high at the very first step in the treatment. SOD is the first-line antioxidant enzyme to convert superoxide radicals into less reactive products and thus minimize oxidative damage. The increased SOD activity that is observed after lemon peel supplementation could be due to the stimulation of endogenous antioxidant protection by citrus bioactive compounds. These results are in accordance with Ebrahimi et al. (2019) who found that dietary citrus waste in broiler chickens significantly increased blood SOD activity from 18.48 U/mg Hb in control birds to 32.61 U/mg Hb at 7.5% citrus waste inclusion ($P = 0.021$). This numerical increase is very suggestive of the antioxidant benefit of citrus-derived products in this study. Abd El-Hack et al. (2023) also found that orange peel meal had a large effect on broiler antioxidant status. SOD increased from 130.33 U/mL in the unsupplemented group to 152.50 U/mL at 240 g/kg orange peel meal ($P = 0.007$). These results are consistent with the general trend in the study, in which citrus peel supplementation increased SOD activity strongly. Akbarian et al. (2014) investigated lemon and orange peel extract in broilers exposed to heat stress. While lemon peel extract produced variable responses, citrus-derived supplementation significantly enhanced antioxidant enzyme activity, and orange peel extract at 400 mg/kg significantly enhanced erythrocyte SOD activity.

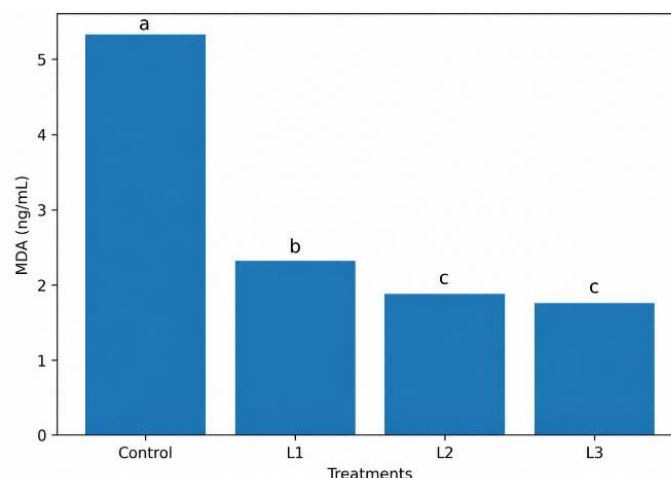


Figure 3. Effect of Lemon Peel Glycerite Extract Supplementation in Drinking Water on Serum Superoxide Dismutase (SOD) Activity in Broiler Chickens Group L1, 2, and 3: add Lemon Peel Glycerite Extract, 0.5, 1, and 1.5 mL/L Drinking Water

Conclusion

Lemon peel glycerite extract improved broiler productive performance and antioxidant status, especially at 0.5-1.0 mL/L drinking water. These levels led to increased body weight gain and final body weight, while 0.5 mL/L had the best feed conversion outcome. Supplementation also decreased lipid peroxidation and enhanced antioxidant defense with lower MDA and higher SOD activity. Moderate lemon peel extract supplementation seems to be an effective natural phyto-genic program to enhance broiler performance and oxidative balance.

REFERENCES

- Ahmed, S. K., & Mustafa, M. M. (2025). Influence of glycerite extraction of lemon peels on broiler performance, carcass characteristics, and physiological traits under heat stress. *Zanin Journal of Science and Engineering*, 1(2), 9–18. <https://doi.org/10.64362/zjse.38>
- Akbarian, A., Golian, A., Gilani, A., Kermanshahi, H., Zhaleh, S., Akhavan, A., De Smet, S., & Michiels, J. (2013). Effect of feeding citrus peel extracts on growth performance, serum components, and intestinal morphology of broilers exposed to high ambient temperature during the finisher phase. *Livestock Science*, 157(2–3), 490–497. <https://doi.org/10.1016/j.livsci.2013.08.010>
- Akbarian, A., Golian, A., Kermanshahi, H., De Smet, S., & Michiels, J. (2015). Antioxidant enzyme activities, plasma hormone levels and serum metabolites of finishing broiler chickens reared under high ambient temperature and fed lemon and orange peel extracts and *Curcuma xanthorrhiza* essential oil. *Journal of Animal Physiology and Animal Nutrition*, 99(1), 150–162. <https://doi.org/10.1111/jpn.12188>
- Behera, D. P., Sethi, A. P. S., Singh, C., Singh, U., & Wadhwa, M. (2019). Effect of citrus waste on blood parameters of broiler birds with and without cocktail of enzymes. *Veterinary World*, 12(4), 483–488. <https://doi.org/10.14202/vetworld.2019.483-488>
- Hafeez, A., Ahmad, I., Naz, S., Alonaizan, R., Al-akeel, R. K., et al. (2023). Effect of lemon (*Citrus limon* L.) peel powder on oocyst shedding, intestinal health, and performance of broilers exposed to *Eimeria tenella* challenge. *Animals*, 13(22), 3533. <https://doi.org/10.3390/ani13223533>
- Jiang, X. R., Zhang, H. J., Wang, J., Wu, S. G., Yue, H. Y., Lü, H. Y., Cui, H., Bontempo, V., & Qi, G. H. (2016). Effect of dried tangerine peel extract supplementation on the growth performance and antioxidant status of broiler chicks. *Italian Journal of Animal Science*, 15(4), 642–648. <https://doi.org/10.1080/1828051X.2016.1222246>
- Ogunlade, J. T., Chukwudi, P., Gabriel, G. O., Akingbade, T. F., Adaramodu, T. T., Adesokan, E. D., Bawa, N. T., Owolabi, S. J., Adebayo, M. K., Olatundun, B. E., et al. (2025). Incremental dietary supplementation with sweet orange (*Citrus sinensis*) peel meal on the growth performance, carcass traits, haematology, serum biochemistry, electrolyte balance, antioxidant status, and humoral immunity in broiler chickens. *Discover Life*, 55, 37. <https://doi.org/10.1007/s11084-025-09716-2>
- Oluremi, O. I. A., Ojighen, V. O., & Ejembi, E. H. (2014). The effects of dietary supplementation of *Citrus sinensis* peel extract on production and quality parameters of broiler chicken. *Journal of Applied Animal Research*. The study evaluated 1000 and 1250 ppm citrus peel extract during different supplementation periods. [Taylor & Francis Online](https://doi.org/10.1007/s11084-025-09716-2)
- Rafiq, S., Kaul, R., Sofi, S. A., Bashir, N., Nazir, F., & Nayik, G. A. (2018). Citrus peel as a source of functional ingredient: A review. *Journal of the Saudi Society of Agricultural Sciences*, 17(4), 351–358. <https://doi.org/10.1016/j.jssas.2016.07.006>
- Sanchez-Casanova, R., Sarmiento-Franco, L., Segura-Correa, J., & Phillips, C. J. C. (2019). Effects of outdoor access and indoor stocking density on behaviour and

- stress in broilers in the subhumid tropics. *Animals*, 9(12), 1016. <https://doi.org/10.3390/ani9121016>
- Seidavi, A., Ebrahimi, A., Alaw Qotbi, A. A., & Gómez Nieto, J. A. (2015). Effect of different levels of *Citrus sinensis* peel extract on broiler performance, blood parameters, thyroid gland activity and bone ash. *Indian Journal of Animal Sciences*, 85(11), 1225–1228. <https://doi.org/10.56093/ijans.v85i11.53282>.
[Icar E-Publications](#)
- Shewita, R. S., El-Naggar, K., & Abd El Naby, W. S. H. (2019). Influence of dietary vitamin C supplementation on growth performance, blood biochemical parameters and transcript levels of heat shock proteins in high stocking density reared broiler chickens. *Slovenian Veterinary Research*, 56, 129–138. <https://doi.org/10.26873/SVR-750-2019>
- Younis, D., Ibrahim, I., & Abdulrahman, S. (2007). Effect of adding vitamin C to drinking water in the physiological and productive performance of broiler chickens reared under high temperature. *Mesopotamia Journal of Agriculture*, 35(4), 39–46. <https://doi.org/10.33899/magrj.2007.26525>
- Yu, D. G., Namgung, N., Kim, J. H., Won, S. Y., Choi, W. J., & Kil, D. Y. (2021). Effects of stocking density and dietary vitamin C on performance, meat quality, intestinal permeability, and stress indicators in broiler chickens. *Journal of Animal Science and Technology*, 63 (4), 815–826. <https://doi.org/10.5187/jast.2021.e77>