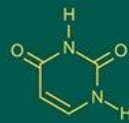


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Effect of lanthanide citrate and cerium citrate supplementation on performance of broilers

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Abstract

The present study was conducted to evaluate the effects of supplementing broiler diets with lanthanide citrate and cerium citrate on their growth performance. A total of 360 one-day-old commercial broiler chicks (Vencobb 430Y strain) were reared over a period of five weeks. The chicks were randomly allocated to six treatment groups, each consisting of six replicates of ten birds. Group A served as the control and received the basal diet, while Groups B, C, D, E, and F were provided the basal diet supplemented with lanthanide citrate and cerium citrate at concentrations of 50, 70, 90, 110, and 120 g per ton of feed, respectively. The results indicated that birds in Group F (120 g/T supplementation) exhibited the highest body weight, greatest weight gain, and superior feed conversion efficiency compared to the control and other supplemented groups. Feed intake was marginally reduced across all supplemented groups, whereas mortality rates remained within the acceptable normative range. The European Production Efficiency Factor (EPEF) was highest in Group C, followed by Group F. In conclusion, the findings suggest that dietary supplementation with lanthanide citrate and cerium citrate, particularly at 120 g per ton of feed, can enhance growth performance in broilers. These additives may be considered effective feed supplements for improving broiler productivity.

Keywords: Lanthanide citrate, cerium citrate, growth performance, broiler

Introduction

The poultry industry represents one of the most rapidly expanding sectors within Indian agriculture, contributing significantly to food production, employment generation, and the national economy. To enhance poultry productivity and health, various feed additives are routinely incorporated into diets. These additives facilitate improved growth rates, feed efficiency, and overall performance, while also aiding in disease management.

In recent years, rare earth elements (REEs) have garnered attention as potential alternatives to antibiotic growth promoters in animal nutrition. REEs encompass elements such as lanthanum, cerium, scandium, yttrium, and several related elements naturally present in the Earth's crust (Redling, 2006) [21]. Among these, lanthanum and cerium have been the focus of extensive study in livestock and poultry nutrition. Prior research indicates that these elements can enhance body weight gain, feed conversion efficiency, egg production, milk yield, and general growth performance. The beneficial effects are attributed to their antimicrobial and antioxidant properties, enhanced enzyme activity, strengthened immune responses, and improved digestion and nutrient absorption. (He and Rambeck, 2000; Cai *et al.*, 2018) [11, 7].

Although REEs share similar chemical characteristics, lanthanum and cerium exhibit distinct biological functions. Lanthanum typically exists in a single stable oxidation state, whereas cerium can exist in two oxidation states, enabling participation in redox reactions and contributing to antioxidant activity (Zhang *et al.*, 2019) [23]. Given their ionic radii are comparable to calcium and other metal ions, these elements may influence metabolic pathways and cellular processes (Cai *et al.*, 2018) [7]. Evidence suggests that organic forms, such as lanthanum citrate and cerium citrate, are more efficacious than their inorganic counterparts (He and Rambeck, 2000; He *et al.*, 2010) [11, 12]. Supplementation with these organic compounds has been associated with enhanced growth performance, nutrient utilization, and metabolic activity in non-ruminant species. (Kraatz *et al.*, 2006; Forster *et al.*, 2008; Cai *et al.*, 2015) [17, 10, 7].

Citric acid and its salts, including lanthanum citrate and cerium citrate, also confer benefits to the digestive system by lowering gastrointestinal tract pH. This acidification inhibits the proliferation of pathogenic bacteria such as *Escherichia coli* and *Salmonella*. Additionally, these compounds stimulate digestive enzyme activity, improve mineral bioavailability, support gut health, and augment nutrient utilization. (Boling-Frankenbach *et al.*, 2001; Nourmohammadi *et al.*, 2012; Islam, 2012; Wu *et al.*, 2024) [4, 19, 14, 22].

Despite encouraging outcomes observed in other animal species, data on the application of rare earth element citrates in poultry remain limited. Accordingly, the present study was undertaken to assess the effects of varying dietary levels of a lanthanum citrate and cerium citrate combination on the growth performance of broiler chickens. The study aimed to establish the potential of these compounds as safe and sustainable growth-promoting feed additives in broiler production.

Materials and Methods

The experiment was conducted over a period of 35 days at the Department of Poultry Science, Mumbai Veterinary College, Goregaon, Mumbai. A total of 360 one-day-old Vencobb 430Y broiler chicks were utilized in the study. The birds were randomly allocated into six groups, each comprising 60 chicks. Each group was further subdivided into six replicates, with 10 birds per replicate. The six groups were subsequently assigned distinct dietary treatments to evaluate the effects of the feed supplements.

Group A: Control diet as per the strain standards

Group B: Control diet supplemented with lanthanide citrate and cerium citrate @ 50 g/T of feed

Group C: Control diet supplemented with lanthanide citrate and cerium citrate @ 70 g/T of feed

Group D: Control diet supplemented with lanthanide citrate and cerium citrate @ 90 g/T of feed

Group E: Control diet supplemented with lanthanide citrate and cerium citrate @ 110 g/T of feed

Group F: Control diet supplemented with lanthanide citrate and cerium citrate @ 120 g/T of feed

All experimental groups were maintained under uniform conditions throughout the duration of the study. The birds were provided with ad libitum access to feed and clean drinking water and were reared on a deep litter system under consistent environmental and management practices. The diets were formulated in accordance with the nutritional requirements recommended for the Vencobb 430Y broiler strain. Distinct feed formulations were administered during the pre-starter, starter, and finisher growth phases. Details of the feed composition utilized in the experiment are presented in Table 1. The nutrient composition of the pre-starter, starter, and finisher diets was determined through proximate analysis, following the procedures outlined by the AOAC (2016) [3], with the results summarized in Table 2.

Table 1: Percent composition of pre-starter, starter and finisher feed

Ingredients	Pre-starter	Starter	Finisher
Maize	58.19	60.39	64.26
Soybean deoiled cake-46%	34.00	32.00	27.50
Meat and bone meal	4.50	4.00	3.50
Oil	0.50	1.00	2.00
Dicalcium phosphate	0.10	0.10	0.10
Limestone powder	0.60	0.50	0.50
Salt	0.23	0.22	0.20
Sodium bicarbonate	0.35	0.35	0.40
DL Methionine	0.28	0.24	0.23
Vitamin premix	0.02	0.02	0.02
Trace mineral mixture	0.02	0.02	0.02
Liver tonic	0.05	0.05	0.06
Toxin binder	0.02	0.02	0.02
Phytase	0.01	0.01	0.01
Salinomycin	0.05	0.05	0.06
Choline chloride	0.12	0.11	0.12
Betaine	0.07	0.08	0.06
Vitamin E	0.01	0.01	0.01
Multienzymes	0.05	0.05	0.05
Limestone powder	0.07	0.07	0.07
Lysine sulphate	0.42	0.38	0.47
L-Threonine	0.14	0.13	0.14
Bentonite powder	0.20	0.20	0.20
Total	100.00	100.00	100.00

Table 2: Proximate analysis of pre-starter, starter and finisher feed

Nutrient	Pre-starter	Starter	Finisher
Moisture (%)	7.97	7.53	8.01
Crude protein (%)	22.54	21.17	19.51
Ether extract (%)	4.10	5.13	5.94
Crude fiber (%)	3.59	3.68	3.43
Total Ash (%)	5.13	5.59	5.03
Nitrogen free extract (%)	56.67	56.90	58.08
Total	100.00	100.00	100.00

During the experiment, important growth parameters such as weekly body weight, feed consumption, feed conversion ratio, mortality rate, and European Production Efficiency Factor were measured. The data collected were then analyzed statistically using one-way ANOVA under a Completely Randomized Design.

Results

Live weights

The average weekly body weights of birds across different groups, from day-old to five weeks of age, are presented in

Table 3. The initial body weights at the day-old stage for Groups A to F were 40.85 ± 0.35 , 40.69 ± 0.41 , 40.65 ± 0.42 , 40.77 ± 0.39 , 40.92 ± 0.31 , and 40.89 ± 0.36 grams, respectively. At the conclusion of the five-week period, the average body weights were 2333.20 ± 20.77 , 2289.16 ± 53.33 , 2286.13 ± 29.90 , 2280.53 ± 34.69 , 2283.52 ± 29.26 , and 2346.65 ± 37.22 grams, respectively. Birds in Group F exhibited the highest final body weight, followed by Groups A, B, C, E, and D. However, the differences in weekly body weights among the groups were not statistically significant ($p \geq 0.05$).

A comparable trend was observed for weight gain, with Group F demonstrating the greatest overall weight gain; nevertheless, the differences among groups were not statistically significant ($p \geq 0.05$).

These results are consistent with those reported by He *et al.* (2010) [12], who noted a numerical increase in body weight in broilers fed diets supplemented with rare earth element (REE) chlorides at 70 mg/kg and REE citrate at 70 and 100 mg/kg relative to the control group. Similarly, Agbede *et al.* (2011) [2] observed only modest improvements in body weight following supplementation with lanthanum oxide (La_2O_3) at levels of 100, 200, and 300 ppm. Likewise, Jo *et al.* (2009) [15] reported increased cumulative weight gain in birds supplemented with cerium (100 ppm) and lanthanum (100 ppm), individually or in combination, though these differences were not statistically significant ($p \geq 0.05$).

Conversely, Mijgar *et al.* (2025) [18] demonstrated that supplementation with lanthanum citrate at 70 mg/kg significantly increased body weight ($P \leq 0.01$) compared to the control group. Similarly, Song and Park (2007) [6] reported a significant enhancement ($P \leq 0.01$) in cumulative weight gain when REEs were incorporated at 100 ppm.

He *et al.* (2010) [12] further explored the mechanisms by which rare earth elements enhance performance in monogastric animals. Ou *et al.* (2000) [20] proposed that REEs may exert their effects through various biological mechanisms, including increased enzyme activity, improved nutrient utilization, and enhanced secretion of digestive fluids. Their findings indicated that the inclusion of small quantities of organic or inorganic REEs in broiler diets can contribute to improved growth performance.

Table 3: ANOVA table for weekly live weights (g) of birds from different treatment groups

Groups	Treatments	Zero-day	Week 1	Week 2	Week 3	Week 4	Week 5
A	Control diet	40.85±0.35	181.24±3.05	496.44±6.20	1018.82±10.98	1677.17±11.67	2333.20±20.77
B	Control + Lanthanide citrate and Cerium citrate @ 50 g/T	40.69±0.41	179.16±3.28	483.71±4.64	994.61±13.87	1631.90±31.15	2289.16±53.33
C	Control + Lanthanide citrate and Cerium citrate @ 70 g/T	40.65±0.42	184.68±3.75	481.21±6.70	985.44±9.72	1619.07±18.82	2286.13±29.90
D	Control + Lanthanide citrate and Cerium citrate @ 90 g/T	40.77±0.39	176.69±4.12	476.86±8.47	980.14±15.27	1619.15±21.60	2280.53±34.69
E	Control + Lanthanide citrate and Cerium citrate @ 110 g/T	40.92±0.31	180.87±1.93	483.31±1.74	992.43±4.54	1624.02±15.66	2283.52±29.26
F	Control + Lanthanide citrate and Cerium citrate @ 120 g/T	40.89±0.36	182.65±2.85	500.48±13.29	1026.33±21.53	1677.96±30.40	2346.65±37.22
SEM		0.14	1.30	3.25	5.92	9.63	14.18
N		6	6	6	6	6	6
P VALUE		0.995	0.609	0.234	0.132	0.204	0.658

Feed consumption

The average weekly feed intake of birds across different groups from the first to the fifth week is presented in Table 4. The total feed consumption per bird over the entire five-week period was 3228.58±44.74, 3165.78±57.51, 3144.57±47.07, 3129.20±52.62, 3132.78±31.47, and 3218.09±49.45 grams for Groups A to F, respectively. Among all groups, birds in Group A exhibited the highest feed intake, followed by Groups F, B, C, E, and D. However, the differences in feed intake among the groups were not statistically significant ($p \geq 0.05$).

These findings are consistent with those of Mijgar *et al.*

(2025) [18], who reported no significant differences in weekly feed intake among broilers supplemented with lanthanum citrate at 70 and 140 mg/kg. Similarly, Jo *et al.* (2010) [16] observed that the inclusion of rare earth elements at 500 ppm in broiler diets did not significantly affect feed consumption. Durmus and Bolukbasi (2015) [8] also reported that supplementation with 400 mg/kg lanthanum oxide in laying hens had no significant impact on feed intake. In accordance, Bolukbasi *et al.* (2016) [5] found that dietary inclusion of cerium oxide at levels of 100, 200, 300, and 400 mg/kg in laying hens did not significantly influence feed intake.

Table 4: ANOVA table for weekly feed consumption (g) of birds from different treatment groups

Groups	Treatments	Week 1	Week 2	Week 3	Week 4	Week 5	Cumulative
A	Control diet	147.18±2.81	395.32±3.31	667.36±8.33	925.49±13.78	1093.23±26.34	3228.58±44.74
B	Control + Lanthanide citrate and Cerium citrate @ 50 g/T	147.47±1.21	385.73±3.69	655.16±9.46	913.27±22.39	1064.16±41.29	3165.78±57.51
C	Control + Lanthanide citrate and Cerium citrate @ 70 g/T	155.35±2.70	386.21±4.25	645.68±7.92	898.95±16.64	1058.37±18.47	3144.57±47.07
D	Control + Lanthanide citrate and Cerium Citrate @ 90 g/T	143.59±2.55	382.07±5.36	644.80±10.49	891.29±17.62	1067.44±25.38	3129.20±52.62
E	Control + Lanthanide citrate and Cerium citrate @ 110 g/T	146.02±1.82	389.50±2.27	649.30±6.63	886.83±13.25	1061.14±17.51	3132.78±31.47
F	Control + Lanthanide citrate and Cerium citrate @ 120 g/T	149.02±2.93	396.08±6.62	665.95±9.65	914.88±16.69	1092.17±18.46	3218.09±49.45
SEM		1.10	1.90	3.68	6.83	10.09	19.29
N		6.00	6.00	6.00	6.00	6.00	6.00
P VALUE		0.039	0.201	0.303	0.565	0.866	0.541

Feed conversion ratio

The average weekly feed conversion ratio (FCR) of birds from the various treatment groups during the first to fifth weeks is presented in Table 5. The cumulative FCR values at the end of the five-week period for Groups A to F were 1.408 ± 0.01 , 1.408 ± 0.02 , 1.400 ± 0.01 , 1.397 ± 0.01 , 1.397 ± 0.01 , and 1.396 ± 0.01 , respectively.

The results demonstrate that birds in Group F, which received a diet supplemented with lanthanide citrate and cerium citrate at 120 g per ton, exhibited a 0.85% improvement in FCR compared to Group A. Similarly, birds in Groups D and E showed a 0.78% enhancement in FCR

relative to Group A. However, these differences in FCR among the groups were not statistically significant ($p \geq 0.05$). These findings align with those of Eleraky and Rambeck (2011) [11], who reported improved FCR in quails supplemented with REE-citrate at 50, 100, and 200 mg/kg, although the differences were not significant ($p \geq 0.05$). Jo *et al.* (2010) [16] similarly observed no significant effect on FCR in birds fed diets containing various rare earth elements and colloidal silver. In contrast, Mijgar *et al.* (2025) [18] reported a significant improvement in feed conversion ratio with the supplementation of lanthanum citrate at 70 mg/kg.

Table 5: ANOVA table for weekly feed conversion ratio of birds from different treatment groups

Groups	Treatments	Week 1	Week 2	Week 3	Week 4	Week 5	Cumulative
A	Control diet	1.049 ± 0.02	1.255 ± 0.02	1.278 ± 0.01	1.406 ± 0.01	1.668 ± 0.03	1.408 ± 0.01
B	Control + Lanthanide citrate and Cerium citrate @ 50 g/T	1.067 ± 0.02	1.267 ± 0.01	1.283 ± 0.01	1.435 ± 0.01	1.624 ± 0.06	1.408 ± 0.02
C	Control + Lanthanide citrate and Cerium citrate @ 70 g/T	1.080 ± 0.02	1.303 ± 0.01	1.281 ± 0.01	1.419 ± 0.01	1.589 ± 0.03	1.400 ± 0.01
D	Control + Lanthanide citrate and Cerium citrate @ 90 g/T	1.058 ± 0.01	1.273 ± 0.01	1.282 ± 0.01	1.397 ± 0.03	1.619 ± 0.03	1.397 ± 0.01
E	Control + Lanthanide citrate and Cerium citrate @ 110 g/T	1.044 ± 0.01	1.288 ± 0.01	1.276 ± 0.01	1.405 ± 0.02	1.611 ± 0.02	1.397 ± 0.01
F	Control + Lanthanide citrate and Cerium citrate @ 120 g/T	1.053 ± 0.03	1.254 ± 0.04	1.267 ± 0.01	1.405 ± 0.02	1.634 ± 0.02	1.396 ± 0.01
SEM		0.01	0.01	0.00	0.01	0.01	0.00
N		6	6	6	6	6	6
P VALUE		0.813	0.429	0.913	0.782	0.716	0.932

Mortality

At the conclusion of the five-week period, the mortality rates for Groups A to F were 3.26%, 1.63%, 0%, 0%, 4.91%, and 1.63%, respectively. Overall, mortality levels across all groups remained within the normal range, indicating that the various treatments did not adversely affect the health of the birds.

European production efficiency factor

The average European Production Efficiency Factor (EPEF) at the end of five weeks was 386.39, 402.90, 411.67, 403.28, 385.87, and 403.36 for Groups A, B, C, D, E, and F, respectively (Fig. 1). The results indicate that birds in Group C exhibited the highest EPEF, followed by Group F, which received lanthanide citrate and cerium citrate at 120 g per ton. Groups B and D, supplemented with 50 g/T and 90 g/T respectively, also demonstrated higher EPEF compared to the control Group A. However, these differences in EPEF among the groups were not statistically significant ($p \geq 0.05$). Limited research is available regarding the impact of lanthanide citrate and cerium citrate on EPEF. Nonetheless, in the present study, the diet supplemented with 90 g/T of these additives yielded the most favorable EPEF performance in broiler production.

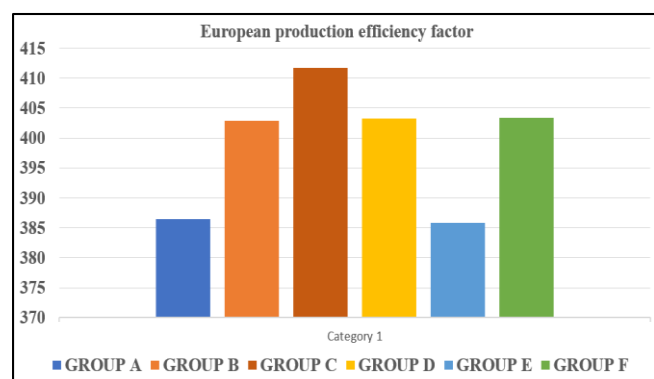


Fig 1: European production efficiency factor (EPEF) of the birds from different groups.

X-axis represents the different groups from A to F and Y-axis represents the European production efficiency factor (EPEF) of the birds.

Conclusion

Lanthanide citrate and cerium citrate can be seen as potential new feed additives. The results of this study, based on different growth parameters, suggest that adding 120 g/T of these compounds to broiler diets may help improve overall growth performance.

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References

1. Abdelnour SA, Abd El-Hack ME, Khafaga AF, Noreldin AE, Arif M, Chaudhry MT, *et al.* Impacts of rare earth elements on animal health and production: highlights of cerium and lanthanum. *Sci Total Environ.* 2019;672:1021-1032.
2. Agbede JO, Arimah AA, Adu OA, Olaleye MT, Aletor VA. Growth-enhancing, health impact and bacteria suppressive property of lanthanum supplementation in broiler chicken. *Arch Zootech.* 2011;14(2):44-52.
3. AOAC. Official methods of analysis. 20th ed. Washington, DC: Association of Official Analytical Chemists; 2016.
4. Boling-Frankenbach SD, Snow JL, Parsons CM, Baker DH. The effect of citric acid on the calcium and phosphorus requirements of chicks fed corn-soybean meal diets. *Poult Sci.* 2001;80(6):783-788.
5. Bolukbasi SC, Al-Sagan AA, Uruan H, Erhan MK, Durmus O, Kurt N. Effects of cerium oxide supplementation to laying hen diets on performance, egg quality, some antioxidant enzymes in serum and

- lipid oxidation in egg yolk. *J Anim Physiol Anim Nutr.* 2016;100(4):686-693.
6. Cai L, Park YS, Seong SI, Yoo SW, Kim IH. Effects of rare earth elements-enriched yeast on growth performance, nutrient digestibility, meat quality, relative organ weight, and excreta microflora in broiler chickens. *Livest Sci.* 2015;172:43-49.
 7. Cai L, Nyachoti CM, Kim IH. Impact of rare earth element-enriched yeast on growth performance, nutrient digestibility, blood profile, and fecal microflora in finishing pigs. *Can J Anim Sci.* 2018;98(2):347-353.
 8. Durmus O, Bolukbasi SC. Biological activities of lanthanum oxide in laying hens. *J Appl Poult Res.* 2015;24(4):481-488.
 9. Eleraky AW, Rambeck WA. Study on performance enhancing effect of rare earth elements as alternatives to antibiotic feed additives for Japanese quails. *J Am Sci.* 2011;7(12):211-215.
 10. Forster D, Berk A, Hoppen HO, Rambeck WA, Flachowsky G. A note on the effect of rare earth elements on the performance and thyroid hormone status of rearing piglets. *J Anim Feed Sci.* 2008;17(1):70-75.
 11. He ML, Rambeck WA. Rare earth elements—a new generation of growth promoters for pigs. *Arch Anim Nutr.* 2000;53(4):323-334.
 12. He ML, Wehr U, Rambeck WA. Effect of low doses of dietary rare earth elements on growth performance of broilers. *J Anim Physiol Anim Nutr.* 2010;94(1):86-92.
 13. IBM Corp. IBM SPSS Statistics for Windows, Version 27.0. Armonk (NY): IBM Corp.; 2020.
 14. Islam KMS. Use of citric acid in broiler diets. *Worlds Poult Sci J.* 2012;68(1):104-118.
 15. Jo JK, Yun K, Kim YW, Kim JS, Kim KH, Kwon IK, *et al.* Effects of dietary supplementation of cerium and lanthanum on growth performance, nutrient digestibility, carcass characteristics and meat colors in broilers. *Asian-Australas J Anim Sci.* 2009;36(4):279-286.
 16. Jo JK, Kim JS, Yun K, Kim YW, Kim KH, Kwon IK, *et al.* Effects of feeding colloidal silver and rare earth elements on growth performance in broilers. *Korean J Poult Sci.* 2010;37(1):1-8.
 17. Kraatz M, Taras D, Männer K, Simon O. Weaning pig performance and faecal microbiota with and without in-feed addition of rare earth elements. *J Anim Physiol Anim Nutr.* 2006;90(9-10):361-368.
 18. Mijgar PV, Gole MA, Desai DN, Ranade AS, Gadhave PD, Pharande RR, *et al.* Effect of lanthanum citrate supplementation on growth performance of broilers. *Indian J Poult Sci.* 2025;60(1):13-17.
 19. Nourmohammadi R, Hosseini SM, Farhangfar H, Bashtani M. Effect of citric acid and microbial phytase enzyme on ileal digestibility of some nutrients in broiler chicks fed corn-soybean meal diets. *Ital J Anim Sci.* 2012;11(1):36-40.
 20. Ou X, Guo Z, Wang J. The effects of rare earth element additive in feed on piglets. *Livest Poult Ind.* 2000;4(2):21-22.
 21. Redling K. Rare earth elements in agriculture with emphasis on animal husbandry [doctoral dissertation]. Munich: Ludwig Maximilian University of Munich; 2006.
 22. Wu X, Zhou Y, Lu Z, Zhang Y, Zhang T, Jiang Q. Cupric citrate supplementation improves growth performance, nutrient utilization, antioxidant capacity, and intestinal microbiota of broilers. *Anim Biosci.* 2024;38(3):530-541.
 23. Zhang M, Zhai X, Luo F, Du Y, Yan C. Antibacterial mechanism and activity of cerium oxide nanoparticles. *Sci China Mater.* 2019;62(11):1727-1739.
 24. Zohravi M. The effect of rare earth elements on growth performance, tibia mineralization and blood serum of Japanese quails [doctoral dissertation]. Munich: Ludwig Maximilian University of Munich; 2007.