Research Article

Study of the Productive Response to Supplementing Drinking Water with Different Concentrations of Certain Nano Amino Acids in Broiler Chickens (Ross 308)

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Abstract | This study aimed to evaluate the effectiveness of supplementing drinking water with different concentrations of essential nano amino acids (methionine and lysine) loaded on zinc on the productive performance of broiler chickens, and to determine the optimal concentrations that yield the best productive responses. The experiment was conducted at the poultry farm, College of Agriculture, Babylon Governorate, from February 10 to March 15, 2025. , A total of 450 Ross 308 broiler chicks were randomly distributed into 30 pens, comprising five experimental treatments with 90 birds per treatment and six replicates (15 birds each). The experimental treatments were as follows: The first group (T1) served as the control and did not receive any supplementation, The second group (T2) received nano methionine at a concentration of 2.5%, added to the drinking water at a rate of 1 ml/L, The third group (T3) received nano methionine at a higher concentration of 3.5%, also added to the drinking water at a rate of 1 ml/L, The fourth group (T4) was supplemented with nano lysine at a concentration of 2%, added to the drinking water at a rate of 1 ml/L, The fifth group (T5) received nano lysine at a concentration of 3%, added to the drinking water at a rate of 1 ml/L, The results revealed a significant improvement ($p \leq 0.05$) in live body weight, total weight gain, feed conversion ratio, and carcass traits in treatments T2, T3, T4, and T5 compared with the control group (T1). Feed intake showed no significant differences among all treatments. Therefore, supplementing drinking water with nano methionine or nano lysine at the aforementioned concentrations resulted in superior productive performance compared to the control.

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Introduction

Nanotechnology offers a broad and diverse field of biological and therapeutic research, in addition to its applications in addressing problems related to environmental conditions. It is a promising and emerging technology with tremendous potential to revolutionize the agricultural and livestock sectors. The term nano is derived from Latin, and the concept of nanotechnology was first introduced in 1959 by the renowned physicist Richard Feynman (Gopi *et al*., 2017). Methionine is one of the essential amino acids vital for mammals and birds. It is a crystalline white solid powder with a characteristic odor (Nelson, 2015; Arkan *et al*., 2025). Methionine belongs to the sulfur-containing amino acids and is classified as a neutral amino acid, containing one amino group (NH_3^+) and one carboxyl group (COO^-), as illustrated in Figure (1). It is an aliphatic α-amino acid, with L-Methionine representing the naturally occurring form, while DL-Methionine and its hydroxy analogue DL-2-hydroxy-(4-methylthio) butanoic acid (DL-HMTBA) serve as industrially produced sources commonly added to poultry diets (Goodson *et al*., 2012).Lysine is another crucial amino acid in broiler chicken diets. The ratio of lysine to other essential amino acids plays a key role in achieving optimal performance in broilers (Corzo *et al*., 2002). Increasing dietary lysine levels has been reported to enhance carcass protein content (Sibbald & Wolynetz, 1986). Lysine requirements are generally higher in low-protein diets to maximize weight gain and feed efficiency (Labadan & Soni, 2001). Zinc is an essential trace mineral in poultry nutrition, required for optimal performance and productivity. It is crucial for cellular proliferation and differentiation and acts as a metallic cofactor for numerous enzymes (Bonaventura *et al*., 2015; Sharif *et al*., 2021). Zinc also plays a fundamental role in stimulating enzymatic reactions, regulating various cellular processes such as protein synthesis, hormone production, feathering, bone development, growth regulation, and membrane stability (Jahanian & Rasouli, 2015; Kwiecien *et al*., 2017; Gammoh & Rink, 2017; Ajafar *et al*., 2024 a,b). Furthermore, it enhances antioxidant activity and contributes to the synthesis of glutathione peroxidase (Saleh *et al*., 2018). Zinc deficiency in poultry diets can therefore negatively affect growth performance and overall health status.

Research hypotheses

This study hypothesizes that supplementing drinking water with zinc-loaded nano methionine or nano lysine will significantly enhance growth performance, feed efficiency, and carcass characteristics of broiler chickens compared with the control treatment. It is further hypothesized that different concentrations of nano amino acids will result in variable productive responses, allowing identification of the optimal supplementation level for broiler production.

Materials and methods

This experiment was conducted at the Poultry Farm, College of Agriculture, Babylon Governorate, from February 10 to March 15, 2025. A total of 450 unsexed Ross 308 broiler chicks were obtained from Al-Anwar Hatchery and randomly distributed into 30 pens. The experiment included five treatments with 90 birds per treatment, each comprising six replicates of 15 birds. Experimental diets were formulated according to the Ross 308 (2022) management guide, consisting of a starter diet (1–11 days), a grower diet (12–24 days), and a finisher diet (25–35 days), as shown in Table 1. The experimental treatments were as follows: The first group (T1) served as the control and did not receive any supplementation , The second group (T2) received nano methionine at a concentration of 2.5%, added to the drinking water at a rate of 1 ml/L , The third group (T3) received nano methionine at a higher concentration of 3.5%, also added to the drinking water at a rate of 1 ml/L , The fourth group (T4) was supplemented with nano lysine at a concentration of 2%, added to the drinking water at a rate of 1 ml/L , The fifth group (T5) received nano lysine at a concentration of 3%, added to the drinking water at a rate of 1 ml/L. The selected supplementation levels of nano methionine and nano lysine were based on previous studies reporting the beneficial effects of nano-form amino acids and their enhanced bioavailability at low inclusion rates (Subramanian & Al Ghaferi, 2013; El-Shobokshy *et al*., 2022; Arkan *et al*., 2025). The applied concentrations were chosen to evaluate both moderate and relatively higher supplementation levels without inducing adverse effects on broiler performance. Zinc was prepared as zinc acetate dihydrate ($Zn(CH_3COO)_2 \cdot 2H_2O$), by dissolving 11 g in 500 mL of distilled water to obtain a 0.1 M solution. The solution was clear and colorless, with a small amount of acetic acid added to enhance solubility. The characterization of the prepared nano compounds was confirmed using Fourier Transform Infrared Spectroscopy (FTIR) and X-ray Diffraction (XRD) analyses. The amino acids were converted into zinc-loaded nano forms according to the method described by Subramanian and Al Ghaferi (2013).

The protein concentrate (Brocon-5 Special W) — of Chinese origin — contained the following per kilogram: 40% crude protein, 3.5% fat, 1% fiber, 6% calcium, 3% available phosphorus, 3.25% lysine, 3.90% methionine + cystine, 2.2% sodium, and 2,100 kcal/kg metabolizable energy.It also provided 20,000 IU of vitamin A, 40,000 IU of vitamin D_3, 500 mg of vitamin E, 30 mg of vitamin K_3, 15 mg of vitamins

$B_1 + B_2$, 150 mg of vitamin B_3, 20 mg of vitamin B_6, 300 mg of vitamin B_{12}, 10 mg of folic acid, 100 µg of biotin, 1 mg of iron, 100 mg of copper, 1.2 mg of manganese, 800 mg of zinc, 15 mg of iodine, 2 mg of selenium, 6 mg of cobalt, and 900 mg of antioxidant (BHT).The chemical composition of the diets was calculated according to Feedstuff (2016).

Table 1: *Composition of the experimental diets and their calculated chemical analysis*

Item / Nutrient	Starter % (1–11 d)	Grower % (12–24 d)	Finisher % (25–35 d)
Feed Ingredients			
Yellow corn	43.00	49.00	50.00
Soybean meal (48% protein)	32.00	27.50	23.00
Wheat	16.00	13.00	16.20
Protein concentrate	5.00	5.00	5.00
Vegetable oil	2.00	3.50	3.75
Limestone	1.25	1.30	1.10
Dicalcium phosphate	0.60	0.50	0.60
L-lysine	0.15	0.10	0.06
Salt	0.00	0.10	0.29
Total	100	100	100
Calculated Composition based Feed stuff (2016)			
Crude protein %	22.90	20.90	19.20
Metabolizable energy (kcal/kg)	3006.00	3138.45	3184.49
Methionine %	0.5008	0.47695	0.4534
Lysine %	1.42	1.2502	1.10
Methionine + Cystine %	0.87	0.82	0.74464
Calcium %	0.932	0.95	0.8522
Available phosphorus %	0.47	0.4406	0.45366

Results and Discussion

In Table 2, the initial body weight showed no significant differences ($p > 0.05$) among all experimental treatments. During the first week, treatments T5 and T3 recorded the highest average body weight compared with the control group (T1), which showed the lowest value. In the second week, treatment T3 achieved the highest mean body weight compared with T1, which recorded the lowest mean. In the third week, treatments T2, T3, T4, and T5 exhibited significantly higher body weights than T1. During the fourth week, treatments T3 and T5 maintained significantly higher body weights compared with T1, which showed the lowest value. By the fifth week, all supplemented treatments (T2, T3, T4, and T5) demonstrated significantly higher average body weights compared with the control (T1), which consistently recorded the lowest body weight.

The observed improvement in growth performance and feed conversion ratio in broiler chickens supplemented with nano methionine and nano lysine can be explained by their enhanced bioavailability and cellular uptake compared with conventional amino acid forms. The nano-sized particles facilitate more efficient intestinal absorption, leading to improved amino acid utilization at the cellular level.

Methionine plays a critical role in protein synthesis, methyl group donation, and antioxidant defense through glutathione synthesis, which contributes to reduced oxidative stress and improved metabolic efficiency. Additionally, nano-methionine has been reported to stimulate the expression of growth-related hormones such as growth hormone (GH) and insulin-like growth factor-1 (IGF-1), thereby promoting muscle accretion and body weight gain.

Similarly, lysine is a key limiting amino acid involved in muscle protein deposition and carcass development. Enhanced lysine availability improves nitrogen retention and muscle fiber growth, which explains the increased body weight gain and improved feed efficiency observed in the supplemented treatments. The nano-form delivery further enhances these effects by minimizing nutrient losses and maximizing metabolic utilization.

The results presented in Table 3 indicate that treatments T5 and T3 recorded the highest average body weight gain compared with the control group (T1), which showed the lowest value.

During the first week, all supplemented treatments (T2, T3, T4, and T5) exhibited significantly higher body weight gains than the control (T1). In the third week, treatments T5 and T3 again showed the highest weight gains compared with T1, which recorded the lowest gain.In the fourth week, no significant differences ($p > 0.05$) were observed among all treatments. By the fifth week, the supplemented treatments (T2, T3, T4, and T5) showed higher weight gains compared with T1, which recorded a value of 571.17 g. For the overall experimental period,

Table 2: *Effect of different treatments on the average body weight (g) of broiler chickens during the experimental weeks.*

Treatment	Mean ± Standard Error (g)					
	Initial weight	Week 1	Week 2	Week 3	Week 4	Week 5
T1	42.16 ± 0.33	147.73 ± c	390.10 ± 2.47 c	807.04 ± 14.63 b	1371.83 ± 31.61 c	1943.00 ± 27.96 b
T2	41.92 ± 0.15	190.75 ± 4.89 ab	492.58 ± 6.61 b	1041.83 ± 14.36 a	1743.00 ± 25.61 ab	2441.50 ± 66.59 a
T3	42.33 ± 0.40	199.75 ± 2.04 a	511.83 ± 5.30 a	1179.17 ± 98.34 a	1799.33 ± 13.99 a	2505.33 ± 20.81 a
T4	41.42 ± 0.32	186.25 ± 3.08 b	492.17 ± 5.62 b	1046.50 ± 11.05 a	1704.33 ± 15.13 b	2400.50 ± 37.27 a
T5	41.92 ± 0.27	199.75 ± 3.74 a	499.33 ± 6.47 ab	1074.00 ± 6.49 a	1781.50 ± 13.65 a	2500.17 ± 39.53 a
Significance	n.s.	**	**	**	**	**

*"Means within the same column bearing different superscript letters differ significantly (P≤ 0.05).n.s. = not significant, ** = P ≤ 0.01."*

Table 3: *Effect of different treatments on the average body weight gain (g) of broiler chickens during the experimental weeks.*

Treatment	Mean ± Standard error (g)					
	Week 1	Week 2	Week 3	Week 4	Week 5	Total
T1	105.56 ± 1.73 c	242.36 ± 3.69 b	416.94 ± 15.68 b	564.78 ± 33.32	571.17 ± 44.56b	1900.83 ± 28.12 b
T2	148.83 ± 4.87 ab	301.83 ± 4.01 a	549.25 ± 9.66 ab	701.17 ± 11.94	698.50 ± 63.87 a	2399.58 ± 66.51 a
T3	157.41 ± 2.19 a	312.08 ± 4.61 a	667.33 ± 100.05 a	620.17 ±107.94	706.00 ± 24.85 a	2463.00 ± 21.10 a
T4	143.83 ± 2.86 b	306.91 ± 3.31 a	554.33 ± 6.46 ab	657.83 ± 14.03	696.17 ± 28.04 a	2359.08 ± 37.08 a
T5	157.83 ± 3.83 a	299.58 ± 4.09 a	574.67 ± 7.93 a	707.50 ± 13.47	718.67 ± 29.14 a	2458.25 ± 39.34 a
Significance	**	**	**	n.s.	*	**

*"Means within the same column bearing different superscript letters differ significantly (P ≤ 0.05).n.s. = not significant, ** = P ≤ 0.01."*

Table 4: *Effect of different treatments on the average feed intake (g) of broiler chickens during the experimental weeks.*

Treatment	Mean ± Standard Error (g/bird)					
	Week 1	Week 2	Week 3	Week 4	Week 5	Total
T1	158.67 ± 0.56	374.67 ± 2.78	760.33 ± 6.94	937.50 ± 10.07	963.33 ± 11.36	3194.50 ± 16.81
T2	158.50 ± 2.17	381.16 ± 3.19	768.50 ± 9.62	947.67 ± 20.85	983.83 ± 19.47	3239.67 ± 24.60
T3	159.83 ± 1.01	382.16 ± 4.26	766.67 ± 8.53	956.50 ± 15.27	103.17 ± 12.42	3278.33 ± 34.06
T4	157.00 ± 1.48	375.00 ± 2.62	755.33 ± 10.88	934.17 ± 22.15	978.50 ± 17.39	3200.00 ± 32.11
T5	158.50 ± 0.95	380.83 ± 3.92	764.33 ± 10.73	940.16 ± 11.83	994.33 ± 19.30	3238.17 ± 31.37
Significance	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

n.s.: not significant

Table 5: *Effect of different treatments on the feed conversion ratio (FCR) of broiler chickens during the experimental weeks.*

Treatment	Mean ± Standard error (kg feed/kg meat)					
	Week 1	Week 2	Week 3	Week 4	Week 5	Total
T1	1.505 ± 0.02 a	1.547 ± 0.03 a	1.839 ± 0.08 a	1.693 ± 0.12 b	1.745 ± 0.15	1.682 ± 0.03 a
T2	1.072 ± 0.04 b	1.263 ± 0.02 b	1.402 ± 0.04 b	1.352 ± 0.03 b	1.486 ± 0.17	1.354 ± 0.03 b
T3	1.106 ± 0.01 b	1.225 ± 0.02 b	1.238 ± 0.12 b	2.96 ± 1.64 a	1.446 ± 0.06	1.331 ± 0.02 b
T4	1.093 ± 0.02 b	1.222 ± 0.01 b	1.363 ± 0.02 b	1.421 ± 0.03 b	1.419 ± 0.07	1.357 ± 0.02 b
T5	1.006 ± 0.02 b	1.272 ± 0.02 b	1.331 ± 0.03 b	1.330 ± 0.02 b	1.396 ± 0.07	1.318 ± 0.02 b
Significance	**	**	**	*	n.s.	**

*Means within the same column bearing different superscript letters differ significantly. *P ≤ 0.05, *P ≤ 0.01, n.s. = not significant.*

all supplemented treatments exhibited higher total body weight gain compared with the control group (T1), which consistently recorded the lowest value.

The results presented in Table 4, which illustrate the average feed intake over the five-week experimental period, showed no significant differences (p > 0.05) among all experimental treatments.

The results presented in Table 5 show the effect of different treatments on the feed conversion ratio (FCR) during the experimental weeks. In the first, second, and third weeks, treatment T5 recorded a significant decrease (p ≤ 0.01) in FCR compared with the control group (T1), while no significant differences (p > 0.05) were observed among treatments T2, T3, and T4 during the same weeks. In the fourth week, treatments T5, T4, and T2 showed a significant improvement (p ≤ 0.05) in feed conversion ratio compared with treatments T3 and T1, which recorded higher (less efficient) values. The results presented in Table 6 show the effect of different treatments on live body weight at slaughter, hot carcass weight, dressing percentage, and carcass cut proportions in broiler chickens.A highly significant difference (p ≤ 0.01) was observed among treatments in live body weight at slaughter. Birds in treatment T3 recorded the highest mean live weight (2333.33 ± 33.33 g), followed by T2 and T5, which exhibited slightly lower values with varying levels of significance. The control group (T1) recorded the lowest mean live weight (1926.67 ± 18.69 g). These findings indicate that supplementation with nano amino acids in treatment T3 clearly enhanced growth performance, leading to higher slaughter weights.

Regarding hot carcass weight, a highly significant difference (p ≤ 0.01) was also detected among treatments. The highest carcass weight was observed in T3 (1866.67 ± 40.13 g), followed by T2 (1741.67 ± 62.47 g), while the lowest value was recorded in T1 (1520.83 ± 29.16 g). This trend corresponds with the live body weight results, indicating a direct relationship between slaughter weight and carcass yield. For the dressing percentage, no significant differences (p > 0.05) were found among treatments, with values ranging between 79.02–80.25%. This suggests that the dietary treatments did not markedly affect dressing percentage, and that the observed increase in live body weight did not translate into a proportional increase in carcass yield. Similarly, no significant effects were found in the relative weights of internal organs (liver, gizzard, and heart), indicating that the treatments did not alter the relative development of these organs compared with total body weight. Regarding main carcass cuts, no significant differences were observed in thigh percentage, whereas back percentage showed a significant difference (p ≤ 0.05), with T5 recording the highest value (8.86 ± 0.39%) and T4 the lowest (7.49 ± 0.59%). In the breast area, no significant differences

Table 6: *Effect of different treatments on live body weight at slaughter, carcass weight, and carcass cut percentages of broiler chickens.*

Trait	Mean ± Standard Error					Significance
	T1	T2	T3	T4	T5	
Live weight at slaughter (g)	1926.67±18.69c	2175.00 ±57.37ab	2333.33 ± 33.33 a	2058.33 ± 53.87 bc	2133.33 ± 98.88 b	**
Hot carcass weight (g)	1520.83 ± 29.16 c	1741.67 ± 62.47 ab	1866.67 ± 40.13 a	1633.33 ± 94.57 bc	1708.33 ± 66.35 abc	**
Dressing percentage (%)	79.02 ± 2.11	79.98 ± 1.02	79.96 ± 0.83	79.06 ± 2.86	80.25 ± 1.44	n.s.
Liver (%)	2.22 ± 0.10	2.25 ± 0.10	2.48 ± 0.13	2.43 ± 0.13	2.47 ± 0.20	n.s.
Gizzard (%)	1.28 ± 0.03	1.36 ± 0.07	1.21 ± 0.11	1.23 ± 0.09	1.18 ± 0.06	n.s.
Heart (%)	0.615 ± 0.03	0.546 ± 0.04	0.534 ± 0.03	0.569 ± 0.02	0.556 ± 0.03	n.s.
Thigh (%)	24.54 ± 0.97	26.07 ± 0.79	25.80 ± 0.94	24.53 ± 2.13	23.48 ± 0.49	n.s.
Breast (%)	30.76 ± 0.14	31.88 ± 0.52	32.31 ± 1.65	31.37 ± 1.21	34.13 ± 1.35	n.s.
Wings (%)	5.21 ± 0.13	5.31 ± 0.18	5.18 ± 0.27	5.73 ± 0.10	5.33 ± 0.18	n.s.
Neck (%)	5.30 ± 0.58 ab	4.28 ± 0.18 c	4.02 ± 0.23 c	5.77 ± 0.35 a	4.57 ± 0.12 bc	**
Back (%)	8.67 ± 0.57 ab	8.42 ± 0.18 ab	8.44 ± 0.19 ab	7.49 ± 0.59 b	8.86 ± 0.39 a	*

*Means within the same row bearing different superscript letters differ significantly. *P ≤ 0.05, *P ≤ 0.01, n.s. = not significant.*

were detected, although birds from T5 tended to have a higher proportion (34.13 ± 1.35%). Similarly, wing percentages showed no significant variation among treatments, ranging between 5.18–5.73%. However, in the neck region, a highly significant difference ($p \leq 0.01$) was observed, with T4 showing the highest proportion (5.77 ± 0.35%), while T2 and T3 recorded the lowest values (4.28 ± 0.18% and 4.02 ± 0.23%, respectively).

The improvement in productive performance observed in the treatments supplemented with nano amino acids, particularly in T2 and T3,T4,T5, may be attributed to the role of nano-form methionine and lysine added to the drinking water of broiler chickens, The results clearly demonstrated that supplementation with methionine sources exerted a positive effect on broiler growth performance, enhanced feed utilization efficiency, and improved meat quality and carcass yield. The remarkable increase in growth performance and feed efficiency indicates that supplemental methionine contributed to the enhancement of broiler productivity, reflecting the strong antioxidant properties of this amino acid. Dietary methionine plays a crucial role in the antioxidant defense system of poultry (Kachungwa Lugata *et al*., 2022). Methionine is also a key component in improving the efficiency of nutrient utilization and maintaining amino acid balance in the diet (Bunchasak *et al*., 2009; Al-Saeedi *et al*., 2024). This balance, in turn, promotes body growth and muscle development, in addition to methionine's involvement in enzyme and hormone synthesis (Lee *et al*., 2023). Furthermore, nano-methionine is believed to have a greater capacity to stimulate insulin-like growth factor (IGF) and growth hormone (GH), both of which play vital roles in promoting growth and improving overall productive performance. El-Shobokshy *et al*. (2022) reported that nano-methionine supplementation upregulated GH gene expression, which positively influenced broiler growth. The results of the current study further revealed that adding nano-methionine to drinking water enhanced body weight, weight gain, and feed conversion ratio, while reducing fat deposition. These findings are consistent with previous reports by Shen *et al*. (2015) and Wickramasuriya *et al*. (2019), who stated that methionine-deficient diets result in a significant reduction in daily fat oxidation rate, feed efficiency, and final body weight, whereas excessive levels of methionine produced no additional benefits beyond the optimal requirement (Peng *et al*., 2018).Similarly, determining lysine requirements for broilers is not only economically important—since lysine deficiency or excess can negatively affect performance and increase feed costs (Dozier *et al*., 2010)—but also critical in designing animal models for molecular nutrition studies. Lysine requirements vary according to factors such as strain, sex, growth phase, and productive performance. For instance, Ross × Ross 708 females require approximately 1.27% digestible lysine from 1 to 14 days of age (Dozier & Payne, 2012), while Hubbard × Cobb 500 females at the same age require around 1.18% lysine. Several studies have reported variable lysine requirements across different strains and ages (Dozier *et al*., 2008, 2009; Jia *et al*., 2010; Bhogoju *et al*., 2016; Mehri *et al*., 2012; Bernal *et al*., 2014). Recent findings indicate that dietary lysine levels have a pronounced impact on daily weight gain and feed conversion ratio in broilers. In the another study, a total lysine level of 1.00% was adopted as a reference based on previous research showing improved performance in slow-growing broilers at this level compared with 0.60% or 1.40% (Chen *et al*., 2017). This confirms the reliability of the current animal model. Lysine deficiency was shown to markedly reduce daily weight gain, feed intake, and abdominal fat percentage in slow-growing chickens, consistent with Yang *et al*. (2009) and Bastianelli *et al*. (2007), likely due to decreased feed consumption under lysine-deficient conditions (D'Mello, 1956). Conversely, excessive lysine intake resulted in reduced weight gain, feed intake, and abdominal fat percentage, as reported by Cengiz *et al*. (2008), Hosseini *et al*. (2009), and Leeson (1987). Additionally, lysine levels did not significantly affect relative liver or thigh weights, aligning with previous studies (Cengiz *et al*., 2008).

Conclusions and Recommendations

Based on the findings of the present study, supplementing drinking water with zinc-loaded nano methionine at a concentration of 3.5% (T3) is strongly recommended, as it resulted in the highest improvements in live body weight, total weight gain, feed conversion ratio, and carcass weight compared with the control and other treatments.

The use of nano lysine at a concentration of 3% (T5) is also recommended, as it demonstrated favorable productive performance and improved feed efficiency, indicating its potential as an effective alternative amino acid source in broiler production systems.

It is recommended that nano-amino acids be administered through drinking water rather than feed, as this method ensures uniform intake, enhanced bioavailability, and efficient metabolic utilization without increasing feed consumption.

Future research is recommended to evaluate the long-term effects, economic feasibility, and molecular mechanisms associated with nano methionine and nano lysine supplementation, particularly under different environmental and management conditions. Further studies should also investigate the interaction between nano-amino acids and other trace minerals or feed additives to optimize nutrient efficiency and sustainable broiler production.

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Novelty Statements

Unlike previous studies that mainly focused on dietary supplementation of conventional amino acids, this study investigates the effect of zinc-loaded nano methionine and nano lysine administered through drinking water on broiler chickens. To the best of the authors' knowledge, this is one of the few studies that evaluates different concentrations of nano amino acids delivered via water rather than feed, providing new insights into improving productive performance and feed efficiency in broiler production.

Author's Contributions

Majeed Hameed Ajafar: Prepared the research plan and laboratory work.
Mohammed Haider Hassoon: Carried out the farmwork and wrote the manuscript.

Generative AI or AI assisted technology statement
The authors declare that no genrative AI was used in the creation of this manuscript.

Conflict of interest
The authors have declared no conflict of interest.

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