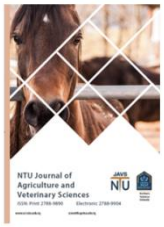
NTU Journal of Agricultural and Veterinary Sciences (2025) 5 (1) : 14-24
DOI: https://doi.org/10.56286/0zs5hb64

IRAQI Academic Scientific Journals

P-ISSN: 2788-9890 E-ISSN: 2788-9904
NTU Journal of Agricultural and Veterinary Sciences
Available online at: https://journals.ntu.edu.iq/index.php/NTU-JAVS/index



Comparison of the Effects of Different Levels of L-Carnitine Supplementation on Growth and Egg Production in Three local Quail Lines Using In Ovo Injection and Dietary Feeding Methods

1st Gulstan Hamadameen Radha[1], 2nd Lajan Salahaldin Ahmed[2], Aihan Jalal Khalil[3], Parizan Wshyar Ibrahim[4]
1,2,3,4. Department of Animal Resources, College of Agricultural Engineering Science, Salahaddin University-Erbil, Iraq

Article Informations

Received: 10-08- 2024,
Accepted: 28-10-2024,
Published online: 28-03-2025

Corresponding author:
Name: Lajan Salahaldin Ahmed
Affiliation : Department of Animal Resources, College of Agricultural Engineering Science, Salahaddin University-Erbil
Email: Lajan.ahmed@su.edu.krd

Key Words:
L- Carnitine,
Ovo Feeding,
Diets Supplementation,
Growth performance,
Quails.

A B S T R A C T

Two studies were conducted to examine the impact of in-ovo injection and dietary addition of L-carnitine (LC) on the growth and egg laying traits of three lines of local quails: desert, brown, and white. The first experiment involved 480 fertile quail eggs were utilized, on the 14th day of incubation, live embryos inside the eggs were injected in the amniotic fluid with varying doses of L-carnitine (0, 4, 8, and 12 mg dissolved in 100 L of a commercial diluent). In the second experiment, 480 one-day-old, unsexed quail chicks were divided into four experimental treatments included: The first group was given the basal diet (control), while the other groups were provided with the basal diet supplemented with different levels of L-carnitine (150, 350, and 500 mg/kg). The evaluation of statistics indicated that quail lines, in-ovo injection, and dietary supplementation with L-carnitine significantly ($p \leq 0.01$) influenced all the studied traits, except for the first egg weight. The interaction between quail line and in-ovo injection treatments was only significant at age of maturity. Conversely, the interaction between the quail line and the dietary supplementation had a significant impact on feed intake, feed conversion ratio, and age at maturity. According to the present results, it can be established that both in ovo injection and dietary supplementation of L-carnitine significantly influenced the productive characteristics traits of quails. In particular, the study revealed that a high in- ovo injection dose of 4 mg/100 µL of diluent and a feed supplement at 350 mg/kg feed resulted in improved production efficiency for quail chicks, except for the initial egg weight, there was no statistically significant association between the feed addition and in-ovo injection treatments.

©2023 NTUJOURNAL OF AGRICULTURAL AND VETERINARY SCIENCES, NORTHERN TECHNICAL UNIVERSITY.
THIS IS AN OPEN ACCESS ARTICLE UNDER THE CC BY LICENSE:**https://creativecommons.org/licenses/by/4.0/**

Introduction

L-carnitine, or β-OH-γ-N-trimethylaminobutyric acid, is a water-based quantum amino acid found naturally in microbes, plants, and mammals. It comes in two stereoisomeric forms, D-carnitine and L-carnitine, which share similar chemical structures but differ in their spatial arrangement of atoms [1]. Only the L-carnitine stereoisomer is biologically active between the two (D-carnitine and L-carnitine) [2]. The synthesis of L-carnitine occurs in the kidneys and liver, involving the use of lysine and methionine, requiring the presence of ferrous ions and three vitamins: ascorbate (vitamin C), niacin (vitamin B3), and pyridoxine (vitamin B6), as described by [3].Poultry producers are looking for methods to enhance growth rates, improve feed conversion efficiency, and reduced the amount of abdominal and subcutaneous body fat in the birds [4]. L-Carnitine is a food additive that can be used to improve the meat production of chicken. There has been growing interest in utilizing LC at recent years. Additionally, it is being explored as a substance to improve physical performance in various applications [5]. L-carnitine is utilized as a dietary supplement in poultry to enhance feed efficiency and meat production, as reported by [6]. LC plays a vital metabolic role by facilitating the transportation of long-chain fatty acids into mitochondria for the process of β-oxidation [7]. By delivering fatty acids into the mitochondria, L-carnitine helps reduce lipid peroxidation, and these fatty acids are used in the production of ATP energy, as noted by [8]. [9] also observed that the inclusion of L-carnitine in the diet has the effect of altering fat metabolism and reducing body fat in poultry. Furthermore, ovo injection has shown to be a cost-effective means of delivering vaccinations to fertilized eggs. Indeed, in ovo feeding of supplemental nutrients can potentially overcome the limitations of the nutrients present in the egg, eggs in modern commercial hatcheries. The injection of nutrients into the amnion of the embryo has become a significant subject in the field of poultry nutrition research. The objective of in ovo feeding is to enhance embryo weight by supplementing embryos with various nutrients throughout the incubation period [10]. The metabolic rate of the embryo rises throughout the last days of incubation, which leads to the consumption of certain nutrients [11], particularly during the crucial final stages of incubation, when the developing embryo has high metabolic requirements [12], it has been observed that chicken embryos have a limited capacity to produce L-carnitine. This limitation is attributed to the insufficient activity of the enzyme -butyrobetaine hydroxylase, which is essential for L-carnitine synthesis during embryonic development [13]. As a result, injecting L-carnitine into the fertilized egg can alleviate embryonic mortality by reducing oxidative stress during the hatching process, ultimately enhancing the viability and hatching success of chicken embryos [14]. A significant portion of the energy required by developing embryos, approximately 90%, is derived from the oxidation of yolk lipids through fatty acid metabolism, and the demand for L-carnitine in chicken embryos is high, as discovered by [14]. Therefore, in ovo injection of L-carnitine may become necessary for facilitating β-oxidation. During the early stages of life, the low level of γ-butyrobetaine is attributed to the limited activity of γ-butyrobetaine hydroxylase. Consequently, providing L-carnitine supplements may be essential to compensate for this deficiency [15].On the other hand, avian embryonic tissues have a high concentration of polyunsaturated fatty acids, which are important components of cell membranes. It is well-known that lipid peroxidation, which is produced by free radicals generated from mitochondria owing to the high metabolic rate of rapidly developing embryos, is particularly susceptible to polyunsaturated fatty acids [16].Hence, the aims of the current study was to assess the impacts of L-carnitine provided through both dietary supplementation and in ovo injection on the growth performance and egg-laying characteristics in three distinct local quail lines.

Materials and Methods

Experimental Procedures

Two experiments were conducted during the period from 21/5/2023 to 25/8/2023 at Grdarasha Station in Quails Research Hall, Animal Resources Department, Agricultural Engineering Sciences College, Salahaddin University-Erbil. The first experiment involved eggs with and without in ovo administration of L-carnitine, while the second experiment focused on post-hatch chicks fed diets with or without the addition of L-carnitine.

First Experimental Incubation and Treatments

Ovo Injection Procedure

In this experiment, a total of 480 fertile eggs (160 eggs per line) were incubated from three different lines of Kurdish quail, obtained from the Agricultural Engineering Sciences College, Salahaddin University-Erbil, Iraq. Fertilized eggs were segregated into four treatment groups using a completely randomized design, and each treatment group had four replicates within each of the three quail lines. The eggs were injected to in ovo supplementation with L-carnitine at various doses on the 14th day of incubation: 0% (the control group, inoculated with sterile distilled water and designated as T1), 4 mg / 100µL L-carnitine (T2 group), 8 mg / 100µL L-carnitine (T3 group), and 12 mg / 100µL L-carnitine (T4 group). The L-carnitine utilized in the experiment was obtained from

Qualikems Fine Chemicals (Delhi, India). Before inoculation, the eggs were carefully incised with an automated needle, and 100 µL of L-carnitine solution at the required concentrations was injected with a 26-gauge needle. Before starting the hatching process, the injection site was sterilized with 70% ethanol and sealed with nail polish.

Grow-Out (Post Hatch)

After hatching, all chicks were individually weighted. A total of 408 hatched birds were divided into 34 cages, each hosting one male and three female quail, with each cage accommodating 12 quails. The dimensions of each cage were 45 cm x 30 cm x 25 cm (length, width, height). All quail chicks were raised under consistent management, sanitary, and environmental conditions until they reached 12 weeks of age.

Second Experiment Diets Supplementation

A total of 480 one-day-old unsexed quails from three different lines of local quail (desert, brown, and white) were randomly divided into four dietary treatments. Each treatment contained three replications and each replicate was housed in a battery cage measuring 45 cm × 30 cm × 25 cm (length, width, height) and containing 12 birds. The chicks were housed in wire cages with one feeder and nipple drinkers under consistent environmental conditions from hatching to 12 weeks of age. Both diets and water were offered ad libitum throughout the experiment. All the birds involved in the experiment were provided with an identical basal diet, which was supplemented as follows: the control group received no additional L-carnitine (0 mg/kg), while Groups 2, 3, and 4 were given the basal diet with L-carnitine supplementation at concentrations of 150 mg/kg, 350 mg/kg, and 550 mg/kg, respectively. The L-carnitine used in this study was sourced from a pharmacy located in Coventry, CV4 9UP, UK. The diets were provided to the quails from 1 to 12 weeks of age.

Experimental Diet

The diet was designed based on the NRC [17] recommendations as outlined in Table 1.The birds were given a grower diet from day 1 to day 42, consisting of 22.26% crude protein and 3049 kcal/kg of energy. After reaching 6 weeks of age, they were transitioned to a layer-quail feed with 23% crude protein and 2,800 kcal/kg ME for the purpose of evaluating egg quality characteristics.

Table 1. Ingredients and diet composition of local quail fed

Ingredient, %	Starter feeds (0-6 weeks)	Grower feeds (After 6 weeks)
Yellow Corn	48	46.4
Wheat	8	8.0
Soyben meal	33.0	34.0
vegetable oil	4.0	4.5
concentration protein *	5	5
Dicalcium phosphate	0.5	0.5
Limestone	1.0	1.0
Salts	0.3	0.3
Vitamins + minerals premix[1]	0.2	0.3
Cystine %	0.33	0.29
Methionine %	0.2	0.2
Lysine%	0.1	0.1
Calsium %	0.9	0.77
Available phosphorous %	0.6	0.32
Calculated value		
Crude proteins, %	23	23
Metabolic energy, kcal/kg	3,150	2,850

The protein concentrate, known as Wafi, is composed of various nutritional components per 1 kilogram of vitamin and mineral premix. These components include 40% crude protein, 5% crude fat, 2.20% crude fiber, 4.20% calcium, 4.68% available phosphorus, 2.50% sodium, 3.70% methionine, 3.70% methionine + cysteine, and 4.12% lysine. In terms of energy content, it provides 2150 kcal per kilogram. Additionally, it contains the following vitamins and minerals: 12.00 IU of vitamin A, 33,000 IU of vitamin D3, 2.5 mg of vitamin B1, 5 mg of vitamin B2, 2 mg of vitamin B6, 0.01 mg of vitamin B12, 50 mg of α-tocopheryl acetate, 0.06 mg of biotin, 2.5 mg of vitamin K, 15 mg of niacin, 0.30 mg of folic acid, 10 mg of pantothenic acid, 600 mg of choline chloride, 60 mg of manganese, 50 mg of iron, 15 mg of zinc, 0.5 mg of iodine, and 0.5 mg of cobalt.

Production Performance Traits

Both experiments involved measuring production traits, including body weight, feed intake, weight gain, feed conversion ratio, egg weight, first egg weight, hen-day egg production, and age at maturity. Evaluation of these characteristics occurred at the conclusion of the study period.

Statistical Analysis

The study utilized a two-way analysis of variance (ANOVA) with a completely randomized design, following the guidelines from SAS (Statistical Analysis System, SAS Institute Inc., Cary, NC, USA). To determine variances between treatments, the multiple range test method described by Duncan, [18] was used. The results were presented as mean values along with the standard error of the mean (SEM), and

statistical significance was assessed at a significance level of ($P \leq 0.05$).The following model was employed for the analysis: $Yijk = \mu + Li + Cj + LCij + eijk$ for both experiments (1, 2) in this study to evaluate lines,(ovo injection and dietary addition) of L-carnitine supplementation and their interaction on growth performance in three different lines of Kurdish quails.

Results and Discussion

In this study, the researchers aimed to enhance the body weight (BW) at 42 days and improve overall weight gain (WG), feed intake (FI), and feed conversion ratio (FCR) in local quails by conducting in ovo injections of L-carnitine (LC) into quail eggs. The results, as shown in Table 2, demonstrate that the experimental groups that received in-ovo injections of L-carnitine showed significant ($P \leq 0.01$) improvements in growth performance parameters compared to the control group. Specifically, injections of L-carnitine at doses of 4, 8, and 12 mg per 100 µL of diluent had favorable effects on various production traits of quails. The injection of 4 mg of L-carnitine per 100 µL of diluent led to increased BW, WG, and improved FCR. These findings are consistent with the research conducted by [19], who found that chicks from eggs injected with L-carnitine had higher BW, WG, and increased FI ($p \leq 0.05$) compared to the control group, with improved feed conversion ratios. Additionally, [20] reported that in ovo injections of 6 or 8 mg of L-carnitine per egg during the pre-incubation period positively influenced hatchability characteristics and the subsequent growth trait of Domyati ducks.

In the examination of the productive performance of quails from different genetic lines, significant differences were observed among the line, with a significance level of ($P \leq 0.05$). The desert line showed higher values for live body weight (LBW), weight gain (WG), and feed conversion ratio (FCR) when compared to the white and brown lines. On the other hand, white quails consumed significantly less feed than the other lines. These variations in performance may be attributed to diverse factors, including the influence of recessive gene action. Indeed, variations in productive performance among quail lines that are fed the same diet and raised under similar farm conditions can be affected by factors with high heritability. Heritability refers to the extent to which a trait is influenced by genetic factors and can be passed on from one generation to the next. High heritability of a trait indicates a substantial influence of genetic factors in determining that trait. [21] proposed that the action of recessive genes may lead to a reduction in quail body weight. These findings clearly indicate that the in ovo injection of L-carnitine at various doses resulted in reduced feed consumption in chicks throughout the entire post-hatching experimental period, in comparison to the control group. Notably, these results display consistent patterns among different poultry species, as supported by studies conducted by [20] on ducks, [22] in broilers, and [23] in turkey breeders. There was no significant interaction was observed between the quail lines and the dietary supplementation of L-carnitine concerning parameters such as final BW, WG, and FCR. However, it's worth noting that the T2 group (which received 4 mg / 100µL L-carnitine) within the white quail line exhibited significantly higher feed consumption during the growth period, as indicated in (Table 2).

Table 2. Impact of interaction between Ovo feeding of L-carnitine and lines on same productive performance traits

lines	Treatments				Probability		
	Ovo feeding of L-carnitine (mg / 100µL)						
	0	4	8	12	L	T	LT
			body weight				
desert	266.80±4.06^{cde}	295.40±4.55^{a}	286.80± 4.16^{ab}	279.80± 3.77^{bc}			
brown	249.13±4.55^{f}	284.60±3.64^{ab}	273.80± 4.14^{bcd}	263.80± 3.29^{de}	<.0001	<.0001	0.9832
white	232.20±5.38^{g}	265.60±6.43^{cde}	254.60± 6.61^{ef}	243.40±4.12^{gf}			
			Body weight gain				
desert	258.00±3.96^{cde}	286.10± 1.95^{a}	277.70± 7.94^{ab}	270.80± 6.23^{abcd}			
brown	239.94±4.61^{ef}	275.64±4.62^{abc}	265.00 ± 8.26^{bcd}	255.24± 3.23^{de}	<.0001	<.0001	0.9942
white	223.80± 4.31^{g}	256.90± 8.36^{de}	246.02± 7.00^{ef}	234.90±3.83^{eg}			
			Feed consumption				
desert	943.53± 2.63^{bc}	884.01±2.51^{g}	914.55±4.33^{ef}	923.77± 2.33^{de}			
brown	993.43±1.97^{a}	921.04±2.76^{de}	952.21± 4.93^{b}	933.97± 6.39^{cd}	<.0001	<.0001	0.0310
white	903.46±3.11^{f}	821.09±6.12^{i}	841.60± 3.76^{h}	877.03± 5.33^{g}			
			Feed conservation ratio				
desert	3.79± 0.39^{bc}	3.01± 0.09^{e}	3.24± 0.06^{cde}	3.36± 0.12^{cde}			
brown	4.40±0.25^{a}	3.20±0.06^{cde}	3.64±0.27^{bcd}	3.73±0.11^{bcd}	0.0131	<.0001	0.9434
white	4.11±0.15^{ab}	3.15± 0.10^{de}	3.46±0.10^{cde}	3.72± 0.18^{bcd}			

$^{a–g}$ Means with different superscripts within the same column and row for each main factor or interaction are significantly different ($P \leq 0.05$).

In Table 3, the data illustrates the impact of dietary supplementation with L-carnitine on various traits related to the performance of different lines of local quail, such as body weight (BW) (after 42 days), mean weight gain (WG), feed intake (FI), and feed conservation ratio (FCR). The study reveals significant enhancements in these productivity traits among different quail lines. Notably, the desert lines outperformed the brown and white lines in terms of body weight (BW) and overall weight gain (WG). This finding supports the results reported by [24, 21], as well as by [25, 26]. On the other hand, the white lines performed better in feed intake (FI) and feed conservation ratio (FCR), consuming the least amount of feed compared to the other lines under study. The results presented in Table 3 highlight how different dietary treatments influence the productive performance of various quail lines. Birds fed diets supplemented with L-carnitine at 350 mg/kg of feed exhibited higher BW, WG, and consumed less feed during the growth period compared to those on a basal diet. This finding is consistent with the observations made by [27], who found that adding 200 ppm of L-carnitine to the diet of Japanese quail for one to four weeks significantly increased weight gain. [1] also reported positive effects of L-carnitine supplementation at different levels (100, 200, and 400 ppm) in Japanese quail diets between 2 and 6 weeks, particularly at the higher level of 400 ppm, on improving BW and FCR. Regarding the interaction between lines and dietary L-carnitine supplementation, there was no significant impact on BW and WG. However, a significant interaction was observed for feed conservation ratio, as shown in Table 3. Specifically, the T3 × desert group displayed the highest BW and WG, while the T3 × White group, among all treatments, exhibited significantly lower FI and FCR ($P \leq 0.05$). In line with these findings, [28] suggest that various quail lines, dietary L-carnitine supplements, and their interactions collectively contribute to improved productivity in quails, as evidenced by increased BW, WG, FI, and FCR.

Table 4, presents the age at maturity (AM), initial egg weight (IEW), egg weight (EW), and hen-day egg production (HDP) following in ovo injection of L-carnitine in different lines of local quail. The results indicate that both quail lines and in ovo injection had significant impacts ($P \leq 0.01$) on certain egg production traits. This aligns with the findings of [29, 30], who also observed the significant influence of lines and genotype on egg weight in quail chicks. [26] reported that the white quail line laid a significantly higher number of eggs compared to desert and brown lines. [31] examined the relationship between genetic distance and genetic variation among three distinct quail lines. They explored how these levels of genetic variation contribute to enhancing growth and egg production performance in this bird species. In this study, the (FEW) did not show significant differences among different quail lines ($P = 0.5054$. While, comparing all L-carnitine (LC) -injected groups, with the control group (without injection) exhibited higher IEW, EW, and HDP and the highest average values were observed in the group treated with 4 mg / 100µL LC, which aligns with the results reported by [27, 32] who found that adding L-carnitine to the diets of laying quails resulted in an increase in EW. The reaction of embryos in various poultry types, such as laying quail eggs, leghorn breeder eggs, and broiler breeder eggs, to supplemental L-carnitine may differ owing to variations in lipid metabolism rates among different strains of egg-type poultry, as observed by [33].The repeated measures analysis has shown that there was no significant interaction effect ($P > 0.05$) between the injection of L-carnitine and the quail lines on egg production traits (EP) Table 4.

Table 3. Impact of interaction between feeding diets of L-carnitine and lines on same productive performance traits

lines	Treatments				Probability		
	Dietary addition of L-carnitine (g/kg)						
	0	150	350	550	L	T	LT
			body weight				
desert	264.80± 3.40^{cd}	274.20± 7.43^{abc}	288.60±2.01^{a}	280.80± 1.85^{ab}			
brown	253.60±2.38^{de}	263.80± 2.67^{dc}	282.40± 6.07^{a}	274.00±6.69^{abc}	<.0001	<.0001	0.9922
white	243.00±1.87^{e}	256.40±1.81^{de}	273.60± 9.37^{abc}	266.00± 2.83^{bcd}			
			Body weight gain				
desert	234.80±2.84^{de}	243.40±1.17^{c}	256.40± 2.25^{a}	250.20±0.80^{b}			
brown	225.20± 2.29^{f}	235.20± 0.58^{ed}	247.60± 2.20^{bc}	244.60±1.21^{bc}	<.0001	<.0001	0.6202
white	216.40±2.01^{g}	229.40±2.66^{ef}	244.40±1.83^{bc}	237.20± 1.93^{d}			
			Feed consumption				
desert	1022.64±4.53^{a}	987.04± 3.13^{c}	925.14± 2.85^{f}	945.66± 3.75^{e}			
brown	998.68± 3.19^{b}	948.46±3.65^{e}	878.73± 3.44^{h}	912.39± 4.28^{g}	<.0001	<.0001	0.0186
white	969.64± 5.41^{d}	920.05±3.66^{fg}	858.40± 2.43^{i}	889.24±3.94^{h}			

			Feed conservation ratio				
desert	3.92± 0.09^{c}	3.64± 0.11^{d}	3.16±0.13^{j}	3.35±0.08^{g}			
brown	3.99± 0.14^{b}	3.61± 0.10^{f}	3.08± 0.12^{l}	3.28± 0.08^{i}	<.0001	<.0001	<.0001
white	4.01± 0.22^{a}	3.63± 0.17^{e}	3.12±0.18^{k}	3.31± 0.14^{h}			

$^{a–g}$ Means with different superscripts within the same column and row for each main factor or interaction are significantly different (P ≤ 0.05).

Table 4. Impact of interaction between Ovo feeding of L-carnitine and lines on egg production trait

lines	Treatments				Probability		
	Ovo feeding of L-carnitine (mg / 100µL %)						
	0	4	8	12	L	T	LT
			Age maturity				
desert	39.20±0.66^{bc}	34.20±0.86	36.00 ± 0.71	37.00± 0.71^{cd}			
brown	41.80±0.58^{a}	37.00 ± 0.84^{cd}	37.80±0.86^{bcd}	40.00± 0.71^{ab}	0.0001	<.0001	0.9150
white	40.00±0.71^{ab}	36.40± 0.81	37.40±1.03^{cd}	38.20± 0.66^{bcd}			
			First egg weight				
desert	9.50±0.14^{b}	10.62± 0.26^{a}	10.56± 0.52^{a}	10.21± 0.22^{ab}			
brown	9.44± 0.19^{b}	10.43± 0.16^{a}	10.38± 0.22^{ab}	10.17± 0.23^{ab}	0.5054	0.0004	0.9846
white	9.83±0.12^{ab}	10.75±0.14^{a}	10.65±0.22^{a}	10.35± 0.19^{ab}			
			Egg weight				
desert	11.00± 0.27^{d}	13.00± 0.11^{ab}	12.83± 0.30^{ab}	12.52±0.18^{b}			
brown	10.50± 0.18^{d}	12.81± 0.16^{ab}	12.58± 0.15^{b}	12.43±0.27^{b}	0.0002	<.0001	0.7791
white	11.75±0.20^{c}	13.35±0.17^{a}	13.13±0.30^{ab}	12.81± 0.31^{ab}			
			H-D egg production				
desert	75.16± 1.52^{f}	87.26± 2.09^{ab}	85.15±0.79^{bc}	82.08± 0.59^{cd}			
brown	72.34± 0.45^{f}	84.35±0.61^{bc}	82.26± 0.53^{cd}	79.82± 0.31^{de}	<.0001	<.0001	0.9819
white	78.63±0.80^{e}	89.08± 2.11^{a}	87.36± 0.82^{ab}	85.54± 0.53^{bc}			

$^{a–d}$ Means with different superscripts within the same column and row for each main factor or interaction are significantly different (P ≤ 0.05).

Table 5 in the study examined the influence of dietary supplementation with L-carnitine on various egg production characteristics in different lines of local quail. The research revealed that both the quail lines and the dietary treatment had a statistically significant impact (P≤0.01) on age at first egg, egg weight (EW), and H-D egg production (HDP). The initial egg's weight (IEW) was not significantly affected by the dietary treatment or the specific quail lines used. Quails that received a basal diet with an addition of 350 mg/kg of L-carnitine (LC) had improved egg production characteristics compared to those that were fed the basal diet without LC supplementation. These findings are consistent with the results of [34], who showed that the significant increase in egg laying by adding L-carnitine at concentrations of 300 and 450 mg/kg of food to the broiler diet when compared to the control diet (T0). However, it's worth mentioning that [35, 36] found that the consumption of 100 mg/kg and 150 mg/kg of L-carnitine increased egg production in laying hens by 7.81% and 10.74%, respectively. Upon examining some of the egg production traits among different quail lines, significant differences (P≤0.01) were observed. The white quail line exhibited higher values for IEW, EW, and HDP compared to the desert and brown lines. In contrast, the desert line showed superiority in age at maturity compared to the other lines. This is consistent with previous research that found significant variations among genotypes and lines in egg weight (EW) traits, as reported by [37, 38], which discovered significant differences in the variances of quail EW among different lines. These results emphasize the significant influence of both genetics and dietary supplementation, particularly with L-carnitine, on egg production (EP) traits in quails.

Table 5. Impact of interaction between feeding dietsof L-carnitine and lines on egg production traits

lines	Treatments				Probability		
	Dietary addition of L-carnitine (g/kg)						
	0	150	350	550	L	T	LT
			Age mturity				
desert	38.60±0.36^{de}	37.20± 0.16^{f}	35.10± 0.35^{h}	35.40± 0.38^{gh}	<.0001	<.0001	<.0001
brown	41.20±0.25^{a}	39.20± 0.22^{cd}	37.60± 0.23^{f}	38.40± 0.20^{e}			
white	40.40± 0.23^{b}	39.60±0.25^{c}	35.80± 0.19^{gh}	36.00± 0.14^{g}			
			First egg weight				
desert	9.74± 0.17^{ab}	10.12± 0.15^{ab}	10.50± 0.22^{ab}	10.18±0.29^{ab}	0.1228	0.0934	0.9984
brown	9.36± 0.19^{b}	9.78± 0.21^{ab}	10.00±0.32^{ab}	9.80± 0.37^{ab}			
white	9.76± 0.19^{ab}	10.20± 0.97^{ab}	10.84± 0.32^{a}	10.40±0.51^{ab}			
			Egg weight				

desert	12.17±0.23^{gf}	12.87±0.14^{cdef}	13.55± 0.38^{abc}	12.97± 0.29^{bcde}	0.0039	0.0184	0.9977
brown	11.67± 0.23^{g}	12.15± 0.23^{fg}	13.04±0.54^{abcd}	12.50± 0.19^{def}			
white	12.23± 0.16^{fg}	13.25±0.20^{abcd}	13.85± 0.12^{a}	13.77± 0.09^{ab}			
			H-D egg production				
desert	82.08± 3.52^{bc}	86.67±2.51^{abc}	90.00± 2.26^{ab}	89.09±1.62^{ab}	<.0001	<.0001	0.7931
brown	84.76±4.03^{abc}	79.33± 2.39^{c}	88.89± 0.88^{ab}	87.08± 2.98^{abc}			
white	85.55±4.25^{abc}	88.00±1.93^{abc}	91.33±1.11^{a}	89.17± 2.59^{ab}			

$^{a-g}$ Means with different superscripts within the same column and row for each main factor or interaction are significantly different ($P \leq 0.05$).

In another study conducted by [30], significant differences were observed among quail lines in of HDP percentage (HD%), with the wild breed illustrating the highest HD% and producing heavier eggs compared to other breeds. Similarly, [39] found that supplementation had a significant impact ($P \leq 0.05$) on egg production in the experimental group when compared to Indian peafowl used as a control. In the context of the current study, there were no significant or interactive effects observed from the combination of quail line × in ovo injection treatment concerning IEW, EW, and daily egg production (HDP). As shown in (Table 5), a significant interaction was observed between the quail line and in ovo injection treatments with respect to the AM.

The study revealed that various growth performance parameters, such as body weight (BW), body weight gain (BWG), feed consumption (FC), feed conservation ratio (FCR), age at maturity (AM), initial egg weight (IEW), weight of eggs (EW), and H-D egg production (HDP), were significantly influenced ($P \leq 0.01$) by in ovo injection with different doses of LC or by adding LC to the feed. Notably, the IEW was not significantly affected ($P > 0.05$) by feed supplementation. These findings are consistent with the research of [23, 41, 22, 20]. Additionally, [39] also reported that broiler growth performance improved when LC was injected compared to a control group. [1] observed that supplementing Japanese quail diets with L-carnitine (at doses of 200-400 mg/kg) had a positive impact on BW, BWG, and FCR. [42] discovered that adding30% L-carnitine to the standard diet improved BW and FC in broilers. Similarly, [34] discovered that supplementing the broiler diet with L-carnitine at dosages of 300 and 450 mg/kg of food resulted in substantial improvements in egg laying, egg weight (EW), and feed conversion ratio(FCR) (g feed/g egg) when compared to a control diet.

These data imply that L-carnitine supplementation can benefit both broiler development and egg production characteristics. The interaction between the two methods of delivering LC (in ovo injection and feed supplementation) was significant ($P < 0.01$) for all traits, except for the initial (IEW) egg weight, which was not significantly affected by the combination of feed supplementation and in ovo injection. In contrast, a prior study by [40] revealed that birds that were administered the maximum in ovo dose of L-carnitine and were provided diets with L-carnitine supplementation experienced a decrease in both body weight (BW) and feed intake (FI) as shown in (Figures 1 and 2).

Conclusions

Based on the presented results, it can be concluded that both in ovo injection of L-Carnitine (LC) on day 14 of embryogenesis and feed supplementation with L-Carnitine significantly enhance productive performance in three different lines of local quail chicks. The study indicates that the use of L-Carnitine, particularly through in ovo delivery at a dose of 4 mg / 100 µL of diluent and as a feed additive at 350 mg/kg feed, is beneficial for improving production efficiency, encompassing growth, egg production (EP), and age at maturity(AM) traits in hatched chicks. These findings point to a positive direction for optimizing the productivity of local quail through targeted L-Carnitine supplementation.

References

[1]. Abdel-Fattah, S.A., and Shourrap, M.I. (2012). Physiological effects of in ovo L carnitine and embryonic thermal conditioning on pre and posthatch development of broiler chicks. In 3rd Mediterranean Poultry Summit and 6th International Poultry Conference, 26-29. https://www.researchgate.net/profile/MohamedShourrap/publication/316441817

[2]. Mc Dowell, L.R. (1989). Vitamins in Animal Nutrition. Ed. Tony J. Cunha, Chapter 16: 393-394, Academic Press, Inc., 1250 Sixth Avenue, San Diego, California92101.http://www.ucv.ve/fileadmin/user_upload/facultad_agronomia/Producion_Animal/Vitamins_in_Animal_and_Human_Nutrition.pdf

[3]. Cave, M. C., Hurt, R. T., Frazier, T. H., Matheson, P. J., Garrison, R. N., McClain, C. J., and McClave, S. A. (2008). Obesity, inflammation, and the potential application of pharmaconutrition. Nutrition in Clinical Practice, 23(1): 16-34. https://doi.org/10.1177/011542650802300116

[4]. Waller, A. (2007). Take a fresh look at broiler nutrition-Feed accounts for most of the cost of broiler production but the most economic option is not always to reduce

feed cost. The impact of the current rise in. Poultry International, 46(9): 12-15.

[5]. Zeyner, A., and Harmeyer, J. (1999). Metabolic functions of L-Carnitine and its effects as feed additive in horses. A review. Archives of Animal Nutrition, 52(2): 115-138. https://doi.org/ 10.1080/17450399909386157

[6]. Baumgartner, M., and Blum, R. (1993). L-carnitine in animal nutrition. vitamine und weitere zusatzstoffe bei mensch und tier (vitamins and other supplements for humans and animals).(G 5. Flachowsky and R Schubert, editors). Friedrich-Schiller Universitaet, Jena, Germany, 413-418. https://www.example.edu/ paper .pdf

[7]. Coulter, D. L. (1995). Carnitine deficiency in epilepsy: risk factors and treatment. Journal of Child Neurology, 10(2): 2S32-2S39. https://doi.org/10.1177/0883073895010002S05

[8]. Nouboukpo, K.E., Tana, K., Kamers. B., Everaert. N. and Willemsen, H. (2010) Effect of In vivo administration of L-carnitine on hatching events and juvenile performance of layer type chicken. International Journal of Poultry Sciences. 9(10), 980-983. https:// cir.nii.ac.jp/crid/11300007953548 22400

[9]. Burtle, G. J., and Liu, Q. (1994). Dietary carnitine and lysine affect channel catfish lipid and protein composition. Journal of the World Aquaculture Society, 25(2): 169-174. https://doi.org/10.1111/j.1749-7345.1994 .tb00178.x

[10]. Coşkun, I., Cayan H., Yilmaz O., Taskin A., Tahtabiçen E., and Samli H. (2014). Effects of in ovo pollen extract injection to fertile broiler eggs on hatchability and subsequent chick weight. Türk Tarım ve Doğa Bilimleri Dergisi, 1(4): 485-489. https://dergipark .org.tr/en/pub/turkjans/issue/13308/160752.

[11]. Yair, R., Shahar, R., and Uni, Z. (2013). Prenatal nutritional manipulation by in ovo enrichment influences bone structure, composition, and mechanical properties. Journal of animal science, 91(6): 2784-2793. https://doi. org/10.2527/jas.2012-5548

[12]. Foye, O. T., Uni, Z., and Ferket, P. R. (2006). Effect of in ovo feeding egg white protein, β-hydroxy-β-methylbutyrate, and carbohydrates on glycogen status and neonatal growth of turkeys. Poultry Science, 85(7): 1185-1192. https://doi.org/10.1093/ps/85 .7.1185

[13]. Arslan, C. (2006). L-carnitine and its use as a feed additive in poultry feeding a review. Revue de médecine vétérinaire, 157(3): 134-142 . https://doi. org/10.1017/S00439339 110 00304

[14]. Salmanzadeh, M., Ebrahimnezhad, Y., and Shahryar, H. A. (2012). Effects of in ovo administration of L-carnitine on hatchability, subsequent performance, carcass traits and blood cholesterol of turkey poults. Revue de Médecine Vétérinaire, 163(10): 448-453.

[15]. Rebouche, C.J. (1992). Carnitine function and requirements during the life cycle. The FASEB Journal, 6(15): 3379- 3386. https://doi.org/10.1096 /fasebj.6.15.1464372

[16]. Kermanshahi, H., Golian, A., Khodambashi Emami, N., Daneshmand, A., Ghofrani Tabari, D., and Ibrahim, S. A. (2017). Effects of in ovo injection of threonine on hatchability, intestinal morphology, and somatic attributes in Japanese quail (Coturnix japonica). Journal of applied animal research, 45(1): 437-441. https://doi.org /10.1080/09712119 .2016 .1206902

[17]. NRC. (1994). Nutrient Requirements of Domestic Animals. Nutrient Requirements of Poultry (9th ed). National Academy Press, Washington, D.C., USA

[18]. Duncan, D.B. (1955). Multiple ranges and multiple F test. Biometrics, 11, 1-42.

[19]. AL-Jomaily, T.K., and Taha, A.T. (2020). Effects in-ovo injection of L-carnitine on hatchability, productive and physiological traits of Japanese quail (Coturnix Japonica). Plant Archives, 20(2): 4051-4055. https://doi. org/ 10.4314/sajas. v42i2.6

[20]. Ghonim, A. I. (2021). An attempt to improve hatchabilty percentage of bronze turkey eggs by technique of in ovo injection with l-carnitine. Egyptian Poultry Science Journal, 41(1): 113-127. https://journals.ekb.eg/article _160059.html

[21]. Inci, H., Sogut, B., Sengul, T., Sengul, A. Y., and Taysi, M. R. (2015). Comparison of fattening performance, carcass characteristics, and egg quality characteristics of Japanese quails with different feather colors. Revista Brasileira de Zootecnia, 44(11): 390-396. https://doi.org/10.1590/S1806-929020 15 001100003

[22]. Rabie, M. H., Ismail, F. S. A., and Ahmed, A. A. S. (2015). Effect of in ovo injection of L-carnitine at different incubational ages on egg hatchability in broiler breeders and post-hatch performance. Asian Journal of Animal and Veterinary Advances, 10 (12): 875-884. https://scialert.net/abstract/? doi= ajava .2015.875.884

[23]. Salmanzadeh, M., Ebrahimnezhad, Y. and Shahryar, H.A. (2013).The effects of in-ovo injection of L-carnitine on hatching traits, growth performance, and carcass characteristics of turkey poults. Bulletin of Environment, Pharmacology and Life Sciences, 2(11): 125-128. https://epsj.journals.ekb.eg/ article _249544.html

[24]. Al-Neemy, M.A.S., Abd Al-Bake, T.M., and Ahmed, F.T. (2014). Effect of genetic group and added fat source in grower ration on some reproductive traits quail. Tikrit Journal for Agricultural Sciences, 14(2): 283- 294 http://www.plantarchives.org/ SPECIAL %20ISSUE%2021-1/19

[25]. Dawood, I.R., Alneemy, M.A., and Hameed, S.M., (2021). Study of the effect of the genetic group, egg weight, and their interaction on the productive performance of quail birds during the growth stage. Plant Archives, 21(1): 98-103

[26]. Ahmed, L.S., and Al-Barzinji, Y.M.S. (2022). Detection of quantitative loci correlation with growth traites in local quail using PCR-RFLP technique. Iraqi Journal of Agricultural Sciences, 53(1):16-26. https://doi.org/ 10.36 103/ijas.v53i1.1501

[27]. Yalçin, S., Ergün, A., Erol, H., Yalcin, S., and Özsoy, B. (2005). Use of L-carnitine and humate in laying quail diets. Acta Veterinaria Hungarica, 53 (3): 361-370. https://doi.org/ 10.1556 /avet.53.2005.3.9

[28]. Mahdi, L.S., Ahmed, L.S., Ibrahim, P.W., and Hamadameen, I.G. (2023). Efficiency of different levels of l-carnitine supplementation on growth performance and blood parameters in three lines of kurdish quails (coturnix coturnix). Iraqi Journal of Agricultural Sciences, 54(6): 1509- 1519.

[29]. Ahmed, L.S., and Al-Barzinji, Y.M.S. (2020). Comparative study of hatchability and fertility rate

among local quails. Iraqi Journal of Agricultural Science, 51(3): 744-751. https://doi.org/10.36103/ijas.v51i3.1028

[30]. Petek, M., Çavuşoglu, E., Odabaşi, F., and Yeşilbağ, D. (2022). Comparison of egg quality characteristics of different quail lines. Journal of Research in Veterinary Medicine, 41(1): 27-31. https://dergipark.org.tr/en/pub/jrvm/issue/71435/1025604

[31]. Ahmed, L.S., and AL-Barzinji, Y.M.S. (2019). Genetic diversity among local quail using RAPD-DNA marker. Revista Cientifica-Facultad de Ciencias Veterinarias, 29(3): 178-185.

[32]. Ibrahim, P.W., Ahmed, L.S., Mahdi, L.S. and Khalil, A.J. (2023). Influence of supplementation of dietary with varying levels of l-carnitine on laying performance and egg quality parameters in different lines of Kurdish quails. Journal of Duhok University, 26(2):72-83.

[33]. Sato, M., Tachibana, T., and Furuse, M. (2006). Heat production and lipid metabolism in broiler and layer chickens during embryonic development. Comparative Biochemistry and Physiology Part A. Molecular and Integrative Physiology, 143(3): 382-388. https://DOI: 10.1016/j.cbpa.2005.12.019

[34]. Rizk, Y.S., Beshara, M.M., Hanan, S.M., and Hassan, A.L. (2022). Impact of supplementing l-carnitine on productive and reproductive performance of mamoura chicken during the winter season. Egyptian Poultry Science Journal, 42 (2): 171-185. https://epsj.journals.ekb.eg/article_249544.html

[35]. Corduk, M., and Sarica, S. (2008). Effects of L-carnitine in layer diets containing different fat sources and energy levels on hen performance and egg quality. South African Journal of Animal Science, 38(3): 260-270. https://hdl.handle.net/10520/EJC94572

[36]. Kazemi-Fard, M., Yousefi, S., Dirandeh, E., and Rezaei, M. (2015). Effect of different levels of L-carnitine on the productive performance, egg quality, blood parameters and egg yolk cholesterol in laying hens. Poultry Science Journal, 3(2): 105-111.

[37]. Ahmed, L.S. (2022). Impact of egg shell and spots colour on the quality of hatching eggs derived from three lines of local quail. Iraqi Journal of Agricultural Sciences, 53(6): 1256-1269. https://doi.org/10.36103/ijas.v53i6.1640

[38]. Ahmed, L.S., and Al-Barzinji, Y.M.S. (2020). Three candidate genes and its association with quantitative variation of egg production traites of local quail by using pcr-rflp. Iraqi Journal of Agricultural Science, 51,124-131. https://doi.org/10.36103/ijas.v51iSpecial.889

[39]. ur Rehman, A., Rafi, U., Yasmeen, R., and Fayyaz, M. (2023). Effects of nutritional supplement E-Sel on the Egg production, Fertility, and Hatchability of Indian peafowl. Journal of Wildlife and Biodiversity, 7(4): 90-100. https://doi.org/10.5281/zenodo.7043125

[40]. Dooley, M., Peebles, E. D., Zhai, W., Mejia, L., Zumwalt, C. D., and Corzo, A. (2011). Effects of L-carnitine via in ovo injection with or without L-carnitine feed supplementation on broiler hatchability and posthatch performance. Journal of Applied Poultry Research, 20(4): 491-497.https://doi.org/10.3382/japr.2010-00280

[41]. Abd El-Azeem, N. A., Abdo, M. S., Madkour, M., and El-Wardany, I. (2014). Physiological and histological responses of broiler chicks to inovo injection with folic acid or L-Carnitine during embryogenesis. Global Veterinary, 13 (4): 544 – 551. https://doi.org/10.5829/idosi.gv. 2014. 13.04 .85231

[42]. Hrnčár, C., Verguliaková, S., Svorad, P., Weis, J., Aprášová, H., Mindek, S., Fik, M. and Bujko, J. (2015). Effect of L-carnitine supplementation on fattening and carcass parameters of broiler chickens. Acta fytotechnica et zootechnica, 18(1):15-19. https://www.academia .edu/download/ 74378301 /131-933-1-PB.pdf

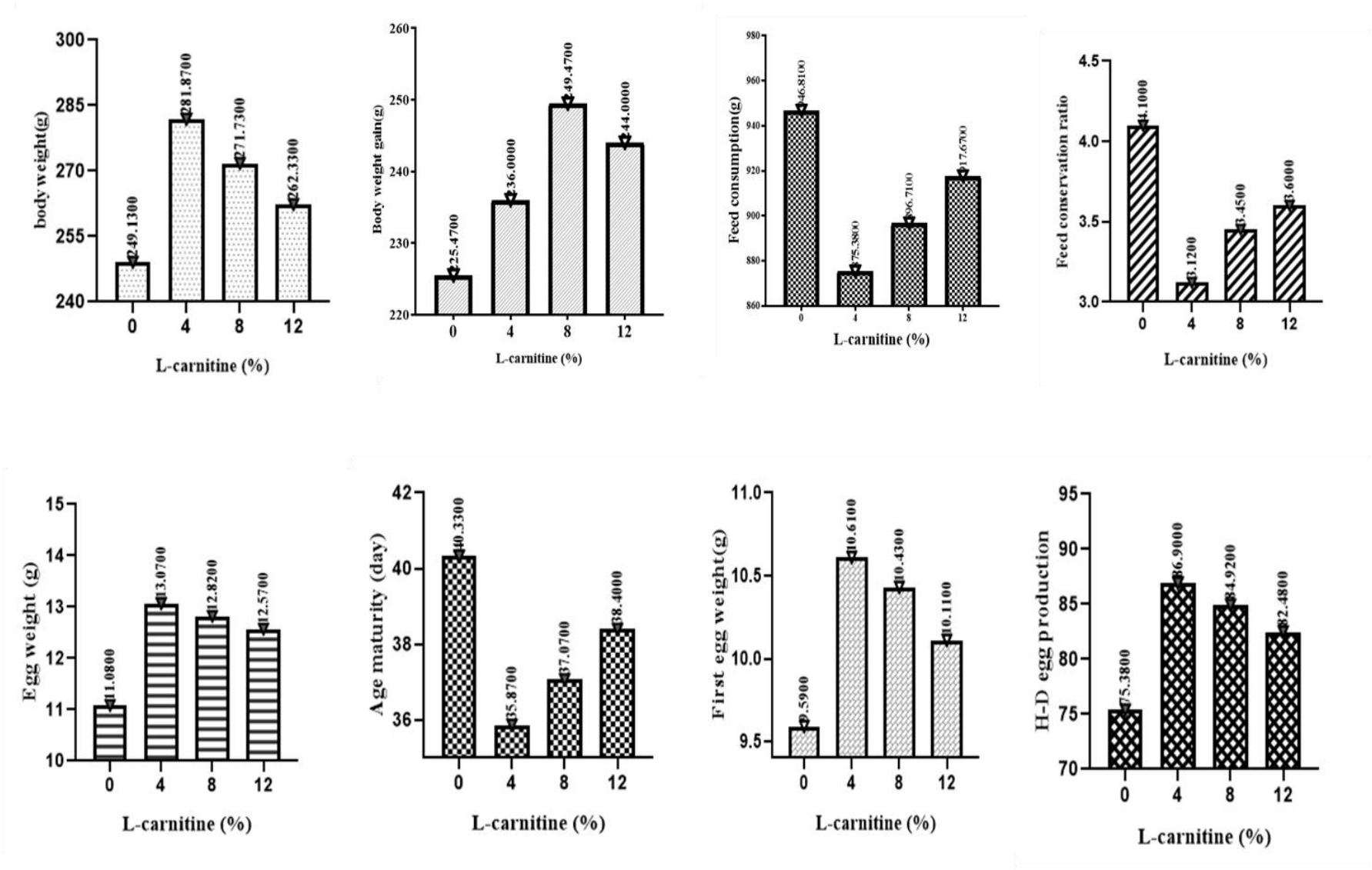


Figure 1. Impact of in ovo injection with L-carnitine on growth performance traits of different lines of local quail chicks

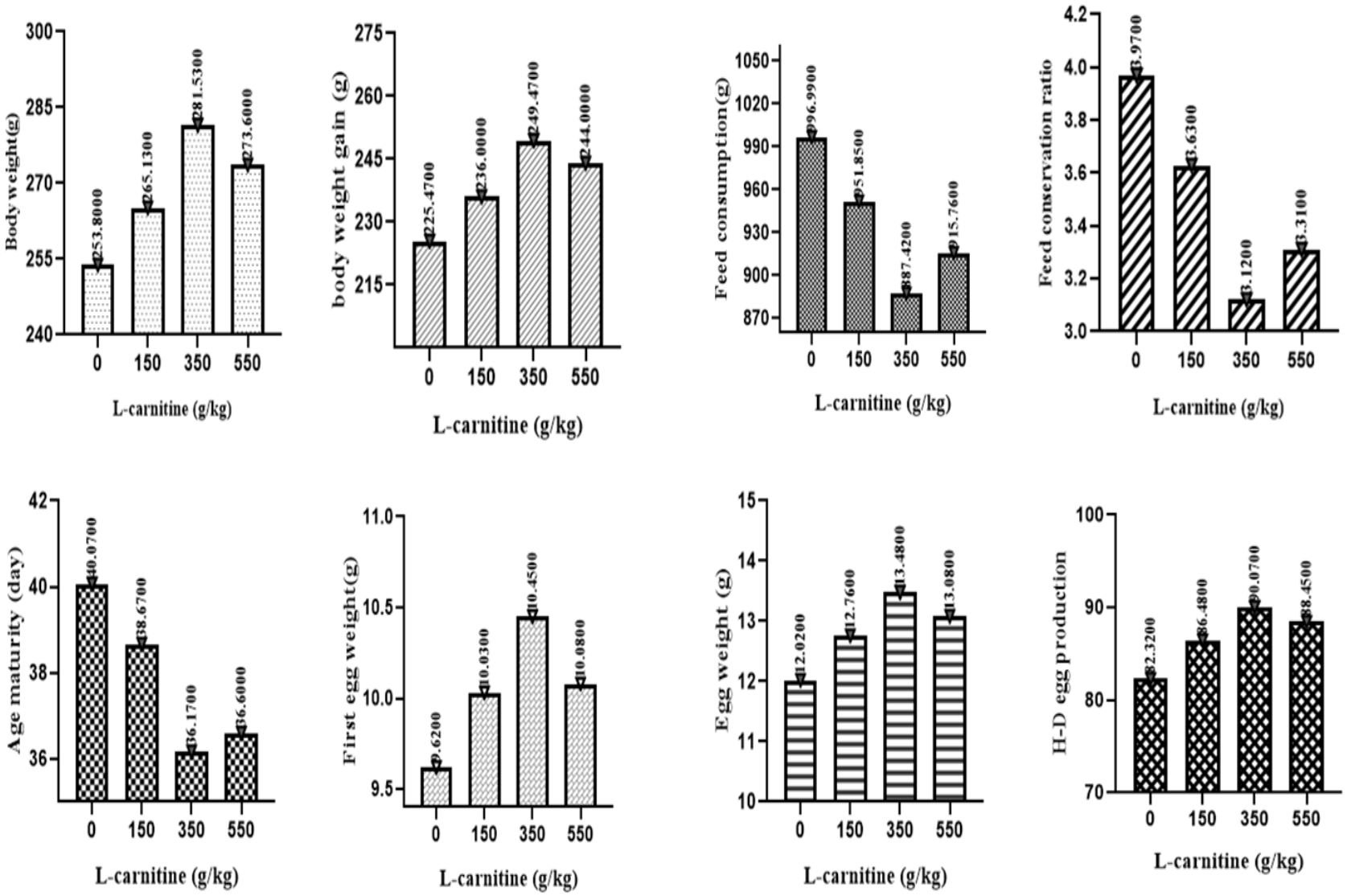


Figure 2. Impact of feed supplementation with L-carnitine on growth performance traits of different lines of local quail chicks