https://doi.org/10.26682/ajuod.2023.26.2.8
Journal of University of Duhok., Vol. 26, No.2 (Agri. and Vet. Sciences), Pp 72-83, 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

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(Received: July 16, 2023; Accepted for Publication: November 21, 2023)

ABSTRACT

The aim of this research was to examine the impacts of lines, L-carnitine, and their combination on laying performance and characteristics of egg quality. A total of 480 newly hatched birds in three lines (desert, brown and white) of Kurdish quail with four levels of L-carnitine (0, 150, 350 and 550 mg/kg)were randomly distributed into four treatments, with each treatment consisting of four replicates, each containing 10 quails and birds were raised from 1 to 12 weeks of age.The results showed that adding different levels of L-carnitine had a higher ($p \leq 0.05$) impact on each quantity of eggs, daily egg production (HD%), and egg weight compared to the control group and affected some egg quality parameters. Furthermore, supplementation with 350 and 550 mg/kg L-carnitine throughout the experimental period significantly improved these characteristics compared with the other experimental treatments having the highest values. As well as for the interacted groups, the white lines with the diet of 350 mg/kg L-carnitine had a significant influence on (HD%), egg weight during 7 -12 weeks of age, and influenced several egg quality characteristics. Except for The addition of L-carnitine to the diet had no significant effect on shape index, yolk height, yolk percentage, shell weight, or shell percentage features. Based on the present results, it can be stated that supplementing the diet with L-carnitine at levels of 350 and 550 mg/kg improves laying performance and some exterior and interior egg quality in three lines of Kurdish quail.

KEYWORDS: L- carnitine, Lines, Laying performance, Egg quality traits, Kurdish quail.

1: INTRODUCTION

Kurdish quail is one of the most important genetic resources due to its adaptation to the environment. Various lines of quail are currently being bred in the Kurdistan region, providing local markets with delicious egg and meat varieties (Ahmed and AL-Barzinji, 2020).It potentially remains the best source of high-quality, cheap animal protein and its rapid growth may make it an ideal research animal for improvement, it short generation interval that allows for many generations to be reproduced per year (4-5 generations per year), and high egg production, short incubation period and high resistance to many poultry diseases (Akarikiya, 2021).In addition, female quail begin laying eggs at the age of 35 days and reach full production when it reaches 50 days, They have a higher egg production rate, early sexual maturity, and the potential to produce up to 350 eggs weighing 10-12 grams in her life, which is 20 times higher than her body weight (Hrnár *et al.,* 2014). Egg
production is regarded as one of the most significant performance indicators of laying hens. Despite the powerful effect of additive genetics in egg production, other factors such as the age at sexual maturity, the bird's weight, nutrition, management, and environmental systems may also impact quail’s egg production (Daikwo *et al.,* 2014; Ahmed and Al-Barzinji, 2020). Ahmed and Al-Barzinji (2019) examined the significant genetic divergence among three distinct quail lines. This observed genetic variation is essential for initiating genetic enhancements aimed at improving the growth and egg production performance of this bird species. Interior and exterior egg quality features play essential for breeding companies. If other management circumstances and fertility are not limiting factors, egg weight, shell weight, shell thickness, yolk weight, and albumen weight are the important egg traits impacting egg quality

and hatching performance (Khurshid *et al.*, 2003). Many factors impacted egg quality characteristics, including the genetic and economic performance of a production flock, as evaluated by the total number of eggs produced (Monira *et al.*, 2003).Numerous research (Gayirbegov *et al.*, 2017; Smolovskaya *et al.*, 2023) and practices indicate that feeding conditions have a significant impact on the production, growth, and development of poultry, including quail. L-carnitine supplementation reduces long-chain fatty acid availability for esterification to triacylglycerols and storage in adipose tissue. Furthermore, L-carnitine possesses antioxidant effects (Xu *et al.*, 2003). L-carnitine is an alternative food supplement in poultry nutrition due to its positive effect on increasing resistance to metabolic disorders, preventing some diseases, strengthening the immune system, improving poultry performance, and its role in metabolic and physiological processes (Carrol *et al.*, 2001; Gropp *et al.*, 1994; Mast *et al.*, 1999).L-carnitine has almost the same effects as vitamins and is involved in numerous metabolic activities within the body, which included lipid breakdown and energy synthesis (Walter *et al.*, 2000; Carrol *et al.*, 2001). The constant addition of L-carnitine to the experimental layer diet resulted in a decrease of total protein, cholesterol, calcium, and phosphorus (Thiemel and Jelinek, 2004). Rabie *et al.*, (1997) observed that dietary L-carnitine has a beneficial effect on the Haugh unit and can recover the components of the dietary portion of the egg during the late laying period. Some measurements, such as egg production and yolk cholesterol content, were unaffected by L-carnitine supplementation during the early laying period. According to a study by Parizadian *et al.*, (2011), the addition of L-carnitine at doses of 125 and 250 mg/kg resulted in a notable reduction in the levels of cholesterol and triglycerides in the egg yolk of quails. The main objective of this research was to explore the impact of different doses of L-carnitine on the productivity measures and egg quality features of three distinct lines of Kurdish quail.

2: MATERIALS AND METHODS

2:1: Location and morphological measurements

A total of 480 newly hatched quail of the three Kurdish lines (desert, brown, and white) were randomly divided into four treatments, with four replicates and ten birds per replicate. The whole experiment lasted for 12 weeks. The study utilized a foundational diet based on the Nutrient Requirements of Poultry from 1994 (NRC, 1994), as shown in Table 1. From 2 to 12 weeks of age, four distinct diets were created for experimentation. T0 (control) basal diet with no L-carnitine inclusion, T1, basal diet with 150 mg/kg of L-carnitine inclusion T2, basal diet with 350 mg/kg of L-carnitine inclusion, and T3, basal diet with 550 mg/kg of L-carnitine inclusion. The Lcarnitine used in this study was obtained from a pharmacy as a pure white powder from Global Napi Pharmaceuticals Company, Egypt. All birds were housed in40 cages for both male and female quails, and each cage held 12 quails in a ratio of one male to three females. The level battery cages (dimension of each cage: 45× 30 × 25 cm) approved at the quails Research Hall in Grdarasha Station, Dept. of Animal Resources, College of Agricultural Engineering Sciences, Salahaddin University-Erbil, from beginning of November 2022 until end of January 2023. The management, hygienic, and environmental conditions (light and temperature) were the same for all of the quail chicks until they were 12 weeks old. During the experiment, diets water and feed was *ad libitum* for all quails.

Table (1):- Composition of local quail feeds during the experiment (%).

Ingredient (%)	Grower ration (0-35) days	Layer ration (after 35 days)
Yellow corn	30	40
wheat	30	26
Soybean meal	30	21
concentration protein *	5	5
Sunflower Oil	3	4
Limestone	1.1	1.0
Salt	0.3	0.3
Dicalcium phosphate	0.5	2.50
Vitamins- minerals	0.1	0.2
Calculated nutrient content (%)		

Crude protein	22.70	18.90
Metabolizable energy (kcal/kg)	2987.50	3149.90
Methionine %	0.47	0.42
Cystine %	0.33	0.29
Lysine%	1.17	0.90
Calsium %	0.9	0.77
Available phosphorous %	0.6	0.32
C/P	133.97	166.66

*Concentration protein (Wafi) comprises 40% crude protein, 5% crude fat, 2.20% crude fiber, 4.20% calcium, 4.68% accessible phosphorus, 2.50% sodium, 3.70% methionine, 3.70% methionine + cysteine, and 4.12% lysine per 1 kg of vitamin and mineral premix (imported from Holland). metabolic energy of 2150 kcal/kg; 200000 IU of vitamin A, 80000 IU of vitamin D3, 600 mg of vitamin E, 50 mg of vitamin K3, 60 mg of vitamin B1 and 140 mg of vitamin B2, 80 mg of vitamin B6, 700 mg of vitamin B12, 20 mg of folic acid, 50 mg of biotin, 1.200 mg of zinc, 200 mg of copper, 20 mg of iodine, 1.000 mg of iron, 5 mg of selenium, 1.600 mg of manganese.

2:2: Data collection

The egg weight (gm) and egg numbers (collected eggs) were recorded daily, from the first day of sexual maturity (5% of birds laid eggs), and continued up to two weeks after maturation, The eggs was measured by using a sensitive electronic scale from each quails hens within lines. The following equations were used to calculate the HD% and egg production per bird.

$$\%\text{H.D}=\frac{\text{Number of eggs laid per week}}{\text{Number of hens alive x Number of days}}\times 100$$ (El-Sheikh *et al.*, 2016)

2:3: Evaluating the quality of eggs

A total of 96 eggs (32 eggs from each line) were randomly collected at 12 weeks of age in order to measure the interior and exterior characteristics of local quail eggs analyses. They collected 8 eggs from each treatment within each line to assess egg yield characteristics. External egg quality traits (egg weight, shape index, shell thickness, shell percentage were measured. During the investigation, a digital display scale with a sensitivity of 0.001g to 1000g was utilized to determine the weight of the eggs. Additionally, a digital Vernier caliper (mm) was used for measuring the length and width of the eggs. The eggshell thickness was measured using a digital. The shells were air-dried and weighted with the shell membrane. The thickness of the shells was measured at the equatorial, blunt, and sharp points, and the average thickness was calculated from the mean values obtained at these locations. To measure internal characteristics of eggs related to their quality, such as the diameter of the yolk, length of the albumen, width of the eggs, albumen index, yolk percent, yolk index, and Haugh unit. Each egg was broken out onto a flat glass cover. A digital calliper and an electronic balance (0.01-g accuracy) were used to measure the diameter and height of the egg yolk and albumen. The yolk and albumen were separated without damaging the egg yolk, and the weight of the egg yolk was measured (Ahmed, 2022).

2:4: Statistical analysis

analysis of variance (ANOVA) to assess the impact of both genetic lines and L-carnitine supplementation, as well as their potential interaction, on the laying performance and egg quality parameters in quails. The General Linear Model procedure, implemented in the SAS (Statistical Analysis System, SAS Institute Inc., Cary, NC, USA) statistical software package. To discern significant differences among the treatment groups, means were separated utilizing Duncan's multiple range tests, with a significance level of 0.05. Results were presented as mean ± standard error.

3: RESULTS & DISCUSSION

3:1: Egg weight traits

Table 2 shows weekly egg weight (EW) analysis patterns in different lines. The egg weight of the three lines of Kurdish quail differed significantly ($p \leq 0.01$) from 7to 12week of age and also indicated that white line recorded the highest value for EW followed by desert and brown. Several researchers stated that there were significant variations among genotypes and lines in egg weight traits, Ahmed and AL-Barzinji, (2020) found significant differences in the variance lines of the quail eggs' weight. Petek *et al.,* (2022) compared three different Japanese quail (wild, white and black) they were observed that wild quail egg weight was significantly heavier than the other quail lines. Hamad and AL-Barzinji, (2023) evaluated three Kurdish quail breeds (desert, brown and white) showed the white breed was significantly superior to other breeds in EW. Supplementing quail diets with L-carnitine (LC) among different treatments during the period from 2 to 12 weeks of age. Birds provided a diet supplemented with 350 mg/kg LC had a greater EW than those fed with diets containing 0 mg/kg LC, 150 mg/kg LC, or 550 mg/kg LC. Meanwhile, during the experiment, the control group had the lowest EW, which is consistent with the findings of (Rabie *et al.,* 1997a; Celik *et al.,* 2004).While, Rabie *et al.*,(1997a) found that supplementing a Hungarian brown hybrid line with 50, 100, or 500 ppm of dietary L-carnitine had no effect on egg weight throughout the late laying phase from 65 to 73 wk.Additionally, Rabie *et al.,* (1998) discovered that adding L-carnitine to hen diets had no impact on egg weight. Furthermore, between the ages of 7 and 12 weeks, there was a significant (P≤ 0.01) interaction impact between lines and dietary supplementation of LC on quail bird egg weight. Yalcin *et al.,* (2005), adding L-carnitine to laying quail diets leads to increase in egg weight. The response of embryos in these three types of poultry (laying quail eggs, leghorn breeder eggs, and broiler breeder eggs) to supplemental L-carnitine may differ because the rates of lipid metabolism differ between egg-type strains of poultry (Sato *et al.,* 2006). The white lines fed with a diet containing 350 mg/kg LC had a significant impact on EW traits compared to the brown lines fed with the control diet during the experimental period.

Table (2):-L-carnitine, lines, and their interactions' effects on egg weight traits of quails

Traits		Egg weight (g)					
		7 weeks	8 weeks	9 weeks	10 weeks	11 weeks	12 weeks
Overall		10.05± 0.10	10.85±0.09	11.21 ± 0.10	11.91± 0.12	12.52± 0.09	12.800± 0.08
Lines (L)							
Desert		10.15± 0.11^{ab}	10.70±0.12^{b}	11.13± 0.15^{a}	11.78± 0.19^{b}	12.41± 0.17^{b}	12.71± 0.13^{b}
Brown		9.76± 0.12^{b}	10.65±0.16^{b}	11.07± 0.18^{a}	11.65± 0.15^{b}	12.17± 0.16^{b}	12.42± 0.13^{c}
White		10.30± 0.26^{a}	11.20±0.18^{a}	11.44± 0.18^{a}	12.31± 0.14^{a}	13.00± 0.15^{a}	13.29± 0.13^{a}
Treatments (T)							
T0= 0%		9.59± 0.11^{b}	10.39±0.20^{b}	10.72± 0.19^{b}	11.42± 0.17^{c}	11.85± 0.21^{c}	12.06± 0.12^{d}
T1=150%		10.06± 0.23^{ab}	10.77±0.17^{ab}	11.13±0.21^{ab}	11.71±0.17^{bc}	12.37± 0.14^{b}	12.64± 0.11^{c}
T2= 350%		10.37± 0.16^{a}	11.18±0.19 ^{a}	11.67± 0.21^{a}	12.46± 0.22^{a}	13.08± 0.21^{a}	13.46± 0.18^{a}
T3= 550%		10.09± 0.21^{ab}	11.05±0.17^{a}	11.38± 0.14^{a}	12.11±0.18^{ab}	12.85± 0.14^{a}	13.16± 0.13^{b}
Interaction(L∗T)							
Desert	0%	9.74± 0.17^{ab}	10.50±0.22^{bc}	10.89± 0.26^{b}	11.45± 0.24^{cd}	11.90± 0. 30^{cd}	12.16± 0.21^{gf}
Desert	150%	10.21± 0.17^{ab}	10.70±0.18^{bc}	11.14± 0.34^{ab}	11.53± 0.29^{bcd}	12.39± 0.17^{bc}	12.73±0.08^{de}
Desert	350%	10.50± 0.29^{ab}	11.00±0.32^{abc}	11.40± 0.60^{ab}	12.80± 0.73^{a}	13.02±0.55^{ab}	13.63±0.48^{abc}
Desert	550%	10.18± 0.28^{ab}	10.87±0.29^{abc}	11.24± 0.16^{ab}	11.89± 0.40^{abc}	12.71± 0.29^{abc}	12.94± 0.22^{ed}
Brown	0%	9.35± 0.16^{b}	9.97±0.24^{c}	10.42± 0.22^{b}	11.08± 0.24d	11.38± 0.46^{d}	11.67± 0.19^{g}
Brown	150%	9.79± 0.30^{ab}	10.56±0.33^{bc}	10.90± 0.35^{b}	11.59± 0.27^{bcd}	12.00± 0.21^{cd}	12.18± 0.14^{gf}
Brown	350%	10.00± 0.17^{ab}	10.98±0.25^{abc}	11.54± 0.32^{ab}	12.00± 0.24^{abc}	12.78±0.32^{abc}	13.08±0.28^{cde}
Brown	550%	9.81± 0.37^{ab}	10.75±0.31^{abc}	11.30± 0.36^{ab}	11.75± 0.37^{bcd}	12.29± 0.18^{bc}	12.54± 0.15^{ef}
White	0%	9.73± 0.25^{ab}	10.63±0.42^{bc}	10.75± 0.45^{b}	11.63± 0.38^{bcd}	12.13± 0.35^{bcd}	12.23± 0.17^{gf}
White	150%	10.17± 0.79^{ab}	11.22±0.37^{ab}	11.50± 0.43^{ab}	12.28±0.20^{abc}	12.95±0.26^{ab}	13.28±0.16^{bcd}
White	350%	10.83± 0.33^{a}	11.74±0.41^{a}	12.08± 0.19^{a}	12.87± 0.09^{a}	13.58± 0.16^{a}	13.92± 0.07^{a}
White	550%	10.25± 0.44^{ab}	11.36±0.24^{ab}	11.55± 0.21^{ab}	12.53± 0.15^{ab}	13.34± 0.13^{a}	13.74± 0.06^{ab}

$^{a-d}$: Statistically significant differences in both mean values with various superscripts in the same column (P≤0.05).

3.2. Hen Day Egg Production (HD%)

Table (3) illustrates the results of egg production characteristics. There were significant variances among the three different lines of quail for egg production traits, while, there was no difference between desert and white lines during the laying period from 9 to12 wk of age in these traits. The result also showed that the brown line had a lower HD percentage than the other two studied lines. Consistent with our results, AL-Kafajy *et al.,* (2018) evaluated three quail breeds (black, white, and brown) for their HD% found a significantly higher HD% in the white quail in 13th week of age. Ahmed, (2021); Ahmed and AL-Barzinji, (2022) detected that there was a significant genetic difference in productive traits among the three lines of Kurdish quail. Petek *et al.,* (2022) observed significant differences among quail breeds for HD percentage as the wild breed produced the highest HD percentage and heavier eggs than the other breeds. On the other hands, absence of any effects of quail breed on HD percentage, reported when compared four different (black, brown, desert and white) breeds of Japanese quail (Ibrahim *et al.*, 2022).Hen-day egg production (%) results affected by adding L-carnitine (LC) in different lines of local quail are presented in Table (3). During the overall period of experiment, the results of hen-day egg production (%) in T3 (350)mg/kg LC was significantly higher than to those fed with diets containing 0, 150 and 550 mg/kg LC, while, the non-addition of LC was the lowest rates. Similar results were found by Rizk *et al.,*(2022) found that adding L-carnitine (300 and 450 mg/kg food) to the broiler diet significantly increased (P≤0.05) egg laying compared to the control diet. However, Corduk and Sarica, (2008); Kazemi-Fard *et al.,* (2015) concluded that dietary intake of 100 and 150 mg/kg L-carnitine increased egg production in laying hens by 7.81 and 10.74%, respectively, because this additive (L-carnitine) improves lipolysis and liver protection. Neuman *et al.,* (2002) found that L-carnitine supplementation increased mitochondrial energy production and in turn, laying intensity in these birds. As well as for the interacted groups white lines fed with a diet containing 350 mg/kg LC possessed higher significantly HD % than other interacted groups. While, the brown lines fed with the control diet had the lower rate of HD %during the experimental period.

Table (3):-L-carnitine, lines, and their interactions' effects on hen - day egg production traits of quails.

Traits		Hen- day egg production					
		7 weeks	8 weeks	9 weeks	10 weeks	11 weeks	12 weeks
Overall		65.42± 1.99	77.18±1.88	82.60 ± 1.33	87.89± 1.18	90.36± 1.09	92.65± 0.97
Lines (L)							
Desert		65.95± 3.74^{ab}	78.62±3.50^{ab}	85.06± 2.08^{a}	89.53± 1.96^{a}	91.88± 1.72^{a}	94.00± 1.67^{a}
Brown		60.53± 2.60^{b}	71.52±2.73^{b}	76.48± 1.60^{b}	83.33± 1.73^{b}	86.40± 1.98^{b}	88.97± 1.54^{b}
White		69.77± 3.75^{a}	81.41±3.24^{a}	86.25± 2.54^{a}	90.80± 2.09^{a}	92.80± 1.74^{a}	94.97± 1.57^{a}
Treatments (T)							
T0= 0%		58.67± 4.50^{b}	71.34±4.17^{b}	78.76± 3.18^{b}	84.09± 2.71^{b}	86.53± 2.66^{b}	89.67± 2.35^{b}
T1=150%		64.06± 3.45^{ab}	77.48±3.61^{ab}	82.51± 2.53^{ab}	87.19±2.85^{ab}	90.36±1.56^{ab}	91.94±1.41^{ab}
T2= 350%		71.96± 3.91^{a}	80.52±2.64^{a}	85.48± 2.27^{a}	91.23±2.18^{ab}	93.29± 2.07^{a}	94.99± 1.92^{a}
T3= 550%		66.97± 3.60^{ab}	79.38±4.31^{ab}	83.63± 2.49^{ab}	89.04± 2.41^{a}	91.25±2.17^{ab}	93.99±1.85^{ab}
Interaction(L∗T)							
Desert	**0%**	60.00± 4.94^{ab}	72.00±11.5^{ab}	80.44± 6.46^{ab}	85.00±4.68^{ab}	87.50±5.59^{ab}	90.01±4.68^{ab}
Desert	**150%**	62.86± 7.28^{ab}	80.00±3.54^{ab}	85.70± 1.71^{ab}	88.00±2.00^{ab}	92.00±2.00^{ab}	93.33±2.72^{ab}
Desert	**350%**	73.33±11.30^{ab}	81.31±5.98^{ab}	87.81± 3.46^{ab}	94.00± 2.45^{a}	95.00±2.24^{ab}	96.67±3.33^{ab}
Desert	**550%**	67.60± 5.93^{ab}	81.17±5.96^{ab}	86.28± 4.26^{ab}	91.11±5.44^{ab}	93.00±4.36^{ab}	96.00±2.45^{ab}
Brown	**0%**	52.00± 5.83^{b}	67.60±5.64^{b}	73.17± 4.92^{b}	80.60± 3.37^{b}	83.00± 3.74^{b}	87.01± 2.78^{b}
Brown	**150%**	57.33± 5.51^{ab}	70.33±8.47^{ab}	75.16± 2.27^{ab}	83.57±3.16^{ab}	86.67±3.33^{ab}	88.49±1.74^{ab}
Brown	**350%**	68.53± 3.68^{ab}	74.66±2.97^{ab}	79.97± 2.95^{ab}	85.14±5.00^{ab}	88.50±5.10^{ab}	90.80±3.83^{ab}
Brown	**550%**	64.23± 3.16^{ab}	73.48±4.60^{ab}	77.60± 2.06^{ab}	84.00±2.81^{ab}	87.43±4.36^{ab}	89.60±4.22^{ab}
White	**0%**	64.00± 11.66^{ab}	74.43±3.35^{ab}	82.67± 5.31^{ab}	86.67±6.24^{ab}	89.10±4.88^{ab}	92.00±5.01^{ab}
White	**150%**	72.00± 3.74^{ab}	82.11±5.74^{ab}	86.67± 6.24^{ab}	90.00±4.08^{ab}	92.40±2.27^{ab}	94.00±2.45^{ab}
White	**350%**	74.00±3.86^{a}	85.60±3.65^{a}	88.68± 4.67^{a}	94.55± 2.24^{a}	96.36± 2.23^{a}	97.50± 2.50^{a}
White	**550%**	69.09± 9.36^{ab}	83.50±11.1^{ab}	87.00± 5.39^{ab}	92.00±3.74^{ab}	93.33±4.08^{ab}	96.36±2.23^{ab}

$^{a-d}$: Statistically significant differences in both mean values with various superscripts in the same column (P≤0.05).

3:3: external egg qualities

The Table (4) displays the mean values of external characteristics of eggs, such as egg weight, egg length, egg width, shape index, and egg volume, for three different lines of Kurdish quail. The present results indicate that the lines had a significant (P≤0.05) effect on egg weight, egg width, and egg volume. There were no significant differences among these lines, With the exception of shape index and egg length, whereas white birds had higher levels of these traits than brown and desert birds, which is completely consistent with this findings reported by (Sari *et al.,* 2012). Nevertheless, in studies conducted by Ahmed and Al-Barzinji, (2020) and Ahmed (2022), significant differences were observed among various quail lines in terms of egg weight, egg breadth, and egg volume. Chimezie *et al.,* (2017) identified that plumage color assortment had significant impacts on exterior egg quality parameters in Japanese quail. The various amounts of L-carnitine supplementation had a significant ($P \leq 0.05$) influence on exterior egg quality. On the other hand, quails fed a basal diet supplemented with (350) mg/kg LC exhibited superior external egg quality than those fed a basal diet with no LC inclusion. These findings are consistent with the results of Rizk *et al.*, (2022), who observed that dietary L-carnitine supplemented with 300 or 450 mg/kg for Mamoura laying hens over the winter improved egg weight and egg mass traits. Daşkran *et al.,* (2009) discovered no significant changes in egg interior quality while utilizing 150 mg/kg of L-carnitine in laying chickens aged 62 to 72 weeks.

Table (4):-L-carnitine, lines, and their interactions' effects on same external egg quality of quails.

Traits		Egg Trait				
		Egg weight (g)	Egg length (mm)	Egg width (mm)	Shape index	Egg volume (cm3)
Overall		12.84±0.14	33.19±0.14	26.57±0.10	80.09±0.26	12.13±0.12
Lines (L)						
Desert		12.87±0.25^{ab}	33.17±0.22^{a}	26.57±0.14^{ab}	80.15±0.40^{a}	12.08±0.18^{b}
Brown		12.37±0.19^{b}	32.87±0.24^{a}	26.26±0.18^{b}	79.88±0.42^{a}	11.71±0.18^{b}
White		13.28±0.25^{a}	33.53±0.23^{a}	26.89±0.17^{a}	80.24±0.54^{a}	12.58±0.19^{a}
Treatments (T)						
T0= 0%		12.01±0.16^{c}	32.68±0.22^{a}	25.89±0.19^{c}	79.21±0.59^{b}	11.401±0.20^{b}
T1=150%		12.75±0.26^{b}	33.43±0.29^{ab}	26.58±0.14^{b}	79.57±0.50^{ab}	12.16±0.21^{a}
T2= 350%		13.53±0.29^{a}	33.61±0.30^{ab}	27.15±0.17^{a}	80.82±0.51^{a}	12.67±0.21^{a}
T3= 550%		13.06±0.26^{ab}	33.04±0.23^{b}	26.67±0.15^{b}	80.75±0.38^{a}	12.27±0.19^{a}
Interaction(L∗T)						
Desert	**0%**	12.16±0.14^{bc}	33.11±0.18^{ab}	26.23±0.21^{cde}	79.22±0.78^{a}	11.51±0.20^{cd}
Desert	**150%**	12.78±0.44^{abc}	33.36±0.54^{ab}	26.46±0.26^{bcd}	79.35±0.79^{a}	12.12±0.38^{abc}
Desert	**350%**	13.60±0.70^{a}	33.21±0.69^{ab}	27.07±0.33^{abc}	81.57±0.83^{a}	12.59±0.47^{ab}
Desert	**550%**	12.94±0.47^{abc}	32.99±0.28^{ab}	26.54±0.23^{bcd}	80.44±0.40^{a}	12.11±0.26^{abc}
Brown	**0%**	11.66±0.22^{c}	31.91±0.27^{b}	25.48±0.35^{e}	79.81±1.21^{a}	10.951±0.32^{d}
Brown	**150%**	12.18±0.33^{bc}	33.21±0.52^{ab}	26.31±0.21^{cde}	79.27±0.89^{a}	11.65±0.33^{bcd}
Brown	**350%**	13.08±0.40^{ab}	33.90±0.37^{a}	26.92±0.38^{acb}	79.41±0.46^{a}	12.46±0.27^{abc}
Brown	**550%**	12.54±0.37^{abc}	32.48±0.31^{ab}	26.31±0.19^{bcd}	81.04±0.66^{a}	11.78±0.25^{bcd}
White	**0%**	12.22±0.39^{bc}	33.02±0.41^{ab}	25.95±0.37^{de}	78.61±1.16^{a}	11.74±0.45^{bcd}
White	**150%**	13.28±0.50^{ab}	33.71±0.56^{a}	26.98±0.18^{abc}	80.09±1.06^{a}	12.71±0.26^{ab}
White	**350%**	13.92±0.41^{a}	33.73±0.53^{a}	27.46±0.17^{a}	81.49±1.03^{a}	12.97±0.34^{a}
White	**550%**	13.70±0.43^{a}	33.66±0.44^{a}	27.17±0.23^{ab}	80.77±0.92^{a}	12.91±0.27^{a}

$^{a-d}$: Statistically significant differences in both mean values with various superscripts in the same column ($P \leq 0.05$).

For the interaction, white birds fed a control diet supplemented with (350) mg/kg LC had a significant increase in exterior egg quality characteristics, providing the highest values when compared to the other interacted groups.

3:4: Egg albumen parameters

The results presented in Table 5 indicate that the different quail lines had a substantial and statistically significant influence ($p \leq 0.05$) on various albumen characteristics, including albumen weight, albumen height, albumen diameter, and Haugh unit. However, there was no significant impact observed for albumen percentage and albumen index. Notably, the white quail lines exhibited higher values in these characteristics in comparison to the other quail lines. This observation is consistent with studies that have reported significant differences in albumen weight and albumen height among different quail lines (Al-Kafajy *et al.,* 2018). Moreover, albumen height is an important trait that can be used to improve egg quality, as eggs with higher albumen height tend to have better internal egg quality (Khawaja *et al.,* 2013).Additionally, Hrncar *et al.,* (2014) found no significant difference (p>0.05) between the laying and meat type of quail for the Haugh unit, with values of 87.28 and 87.56, respectively. Furthermore, the inclusion of L-carnitine resulted in an improvement of albumen parameters compared to the control treatment, particularly albumen characteristics were found to be greatest in quail groups fed diets with 350 and 550 mg/kg L-carnitine.

Table (5):- L-carnitine, lines, and their interactions' effects on albumen parameters of quails.

Traits		Egg Trait					
		Albumen weight (g)	**Albumen height (mm)**	**Albumen diameter (mm)**	**Albumen percentage (%)**	**Albumen index**	**Haugh unit**
Overall		7.03±0.09	4.43±0.06	41.33±0.30	54.74 ±7.61	10.71±0.12	88.24±0.28
Lines (L)							
Desert		7.12±0.15^{ab}	4.39±0.08^{ab}	40.93±0.45^{b}	54.50±0.42^{a}	10.72±0.17^{a}	87.98±0.43^{b}
Brown		6.75±0.14^{b}	4.31±0.09^{b}	40.83±0.39^{b}	54.47±0.44^{a}	10.55±0.15^{a}	87.89±0.42^{b}
White		7.24±0.17^{a}	4.60±0.12^{a}	42.25±0.62^{a}	55.29±0.47^{a}	10.88±0.17^{a}	88.85±0.60^{a}
Treatments (T)							
T0= 0%		6.65±0.19^{b}	4.07±0.10^{c}	39.46±1.41^{b}	53.58±0.51^{ab}	10.30±0.23^{c}	86.69±0.63^{b}
T1=150%		7.05±0.18^{ab}	4.38±0.09^{b}	41.64±0.38^{a}	55.22±0.54^{a}	10.52±0.16^{bc}	88.04±0.48^{ab}
T2= 350%		7.29±0.20^{a}	4.71±0.11^{a}	42.67±0.58^{a}	55.39±0.63^{ab}	11.05±0.21^{a}	89.35±0.51^{a}
T3= 550%		7.15±0.16^{ab}	4.57±0.08^{ab}	41.57±0.47^{a}	54.75±0.34^{ab}	10.99±0.26^{ab}	88.88±0.41^{a}
Interaction(L∗T)							
Desert	**0%**	6.90±0.45^{ab}	4.18±0.16^{cde}	39.92±0.54^{cd}	53.16±0.68^{ab}	10.48±0.41^{b}	87.30±0.93^{bc}
Desert	**150%**	7.16±0.32^{ab}	4.32±0.19^{bcde}	41.05±0.59^{ad}	55.06±0.81^{b}	10.52±0.39^{b}	87.61±1.18^{bc}
Desert	**350%**	7.26±0.45^{ab}	4.51±0.11^{bcd}	42.12±1.43^{ac}	54.90±1.05^{b}	10.75±0.29^{b}	88.29±0.54^{bc}
Desert	**550%**	7.14±0.25^{ab}	4.53±0.17^{bcd}	40.61±0.75^{bd}	54.66±0.33^{b}	11.11±0.26^{ab}	88.70±0.74^{ac}
Brown	**0%**	6.36±0.12^{b}	4.04±0.13^{de}	39.50±0.77^{cd}	54.32±0.63^{b}	10.23 ±0.21^{b}	86.87±0.61^{bc}
Brown	**150%**	6.72±0.31^{ab}	4.24±0.15^{bcde}	40.98±0.47^{ad}	55.06±1.15^{b}	10.33±0.27^{b}	87.59±0.82^{bc}
Brown	**350%**	7.04±0.34^{ab}	4.47±0.18^{bcde}	42.23±0.97^{ac}	54.902±1.3^{ab}	10.59±0.28^{b}	88.39±1.80^{bc}
Brown	**550%**	6.86±0.25^{ab}	4.48±0.18^{bcde}	40.61±0.44^{bd}	54.66±0.58^{b}	11.03±0.37^{ab}	88.70±1.05^{ac}
White	**0%**	6.68±0.37^{ab}	3.98±0.25^{e}	38.96±1.74^{d}	53.26±0.34^{a}	10.18±0.21^{b}	85.89±1.62^{c}
White	**150%**	7.26±0.37^{ab}	4.58±0.05^{bc}	42.87±0.62^{ab}	55.96±0.62^{b}	10.71±0.18^{b}	88.91±0.17^{ab}
White	**350%**	7.56±0.22^{a}	5.13±0.15^{a}	43.66±0.40^{a}	56.74±0.85^{b}	11.80±0.28^{a}	91.37±0.57^{a}
White	**550%**	7.46±0.29^{a}	4.71±0.07^{ab}	43.50±0.39^{a}	55.18±1.33^{b}	10.83±0.17^{b}	89.24±0.28^{ab}

$^{a-d}$: Statistically significant differences in both mean values with various superscripts in the same column (P≤0.05).

The result of the current study was similar to the results observed by Rabie *et al.,* (1997) and Kita *et al.,* (2005), which reported that supplementing laying hens with 50 and 500 mg/kg of L-carnitine enhanced albumen quality and Haugh unit. This improvement can be attributed to the increased metabolic rate for egg formation in the magnum and the stimulation of ovomucin secretion. Ghods-Alavi *et al.,* (2017) illustrated that the addition of 100 mg/kg of L-carnitine to the diet of laying hens resulted in . increasing of albumen height and Haugh unit. This could be attributed to an improved ratio of albumen to yolk and a reduction in harmful lipids present in the egg yolk (particularly cholesterol). About the interaction, the white birds were provided with a basal diet that supplemented with (350) mg/kg LC showed a significant superiority in external egg quality (albumen parameters), as it gave the highest values compared the other interacted groups

Table (6):- L-carnitine, lines, and their interactions' effects on yolk parameters of quails.

Traits		Egg Trait					
		Yolk weight (g)	Yolk height (mm)	Yolk diameter (mm)	Yolk percentage (%)	Yolk index	Yolk/albumen ratio
Overall		4.12±0.06	11.48±0.09	26.33±0.17	32.04±0.25	43.67±0.31	58.59±0.57
Lines (L)							
Desert		4.10±0.12^{ab}	11.54±0.18^{a}	25.59±0.30^{b}	31.80±0.52^{a}	45.12±0.65^{a}	57.60±1.08^{b}
Brown		3.94±0.08^{b}	11.37±0.16^{a}	26.30±0.30^{b}	31.87±0.40^{a}	43.32±0.45^{b}	58.41±0.80^{ab}
White		4.31±0.09^{a}	11.53±0.09^{a}	27.09±0.17^{a}	32.46±0.36^{a}	42.57±0.26^{b}	59.76±1.05^{a}
Treatments (T)							
T0= 0%		3.77±0.06^{c}	11.28±0.19^{a}	25.68±0.39^{b}	31.73±0.55^{a}	43.93±0.67^{a}	57.06±1.35^{b}
T1=150%		4.06±0.11^{bc}	11.63±0.19^{a}	26.62±0.29^{a}	31.84±0.50^{a}	43.81±0.64^{a}	57.79±1.26^{b}
T2= 350%		4.45±0.12^{a}	11.60±0.15^{a}	26.93±0.32^{a}	32.67±0.56^{a}	43.06±0.40^{a}	61.22±0.85^{a}
T3= 550%		4.18±0.12^{ab}	11.42±0.15^{a}	26.08±0.28^{ab}	31.94±0.36^{a}	43.87±0.72^{a}	58.28±0.82^{ab}
Interaction(L∗T)							
Desert	**0%**	3.70±0.06^{d}	11.44±0.45^{a}	24.79±0.56^{d}	31.63±1.18^{a}	45.30±1.57^{ab}	53.71±1.30^{c}
Desert	**150%**	4.04±0.25^{ad}	11.93±0.45^{a}	26.30±0.65^{abd}	31.51±1.09^{a}	45.40±1.59^{ab}	56.38±2.23^{bc}
Desert	**350%**	4.60±0.27^{a}	11.43±0.23^{a}	26.16±0.67^{acd}	32.73±1.46^{a}	43.73±0.58^{ab}	63.50±1.36^{a}
Desert	**550%**	4.06±0.18^{ad}	11.37±0.35^{a}	25.12±0.33^{cd}	31.34±0.30^{a}	46.04±1.36^{a}	56.80±0.78^{bc}
Brown	**0%**	3.66±0.13^{d}	11.17±0.33^{a}	25.60±0.80^{bcd}	31.03±0.77^{a}	43.68±0.52^{ab}	57.53±1.65^{ac}
Brown	**150%**	3.84±0.07^{cd}	11.40±0.34^{a}	26.56±0.60^{abc}	31.62±0.72^{a}	43.21±0.79^{ab}	57.51±0.14^{ac}
Brown	**350%**	4.24±0.17^{ad}	11.46±0.38^{a}	26.97±0.47^{ab}	32.82±1.01^{a}	42.47±1.01^{b}	60.38±1.64^{ab}
Brown	**550%**	3.70±0.06^{ad}	11.44±0.45^{a}	24.79±0.56^{abd}	31.63±1.18^{a}	46.04±1.36^{a}	53.71±1.30^{ac}
White	**0%**	3.96±0.04^{bd}	11.21±0.25^{a}	26.66±0.46^{abc}	32.52±0.97^{a}	42.07±0.76^{b}	59.95±3.14^{ab}
White	**150%**	4.30±0.19^{ac}	11.57±0.14^{a}	27.01±0.16^{ab}	32.39±0.87^{a}	42.83±0.43^{ab}	59.49±2.43^{ac}
White	**350%**	4.52±0.16^{ab}	11.90±0.09^{a}	27.65±0.35^{a}	32.45±0.27^{a}	42.99±0.40^{ab}	59.79±1.02^{ac}
White	**550%**	4.46±0.23^{ab}	11.46±0.10^{a}	27.05±0.30^{ab}	32.49±0.83^{a}	42.37±0.49^{b}	59.81±2.08^{ac}

$^{a-d}$: Statistically significant differences in both mean values with various superscripts in the same column ($P \leq 0.05$).

3:5: Egg yolk parameters

Table 6 displays the results of analyzing the yolk parameters of three quail lines with various plumage colors. Data from yolk weight, yolk diameter, yolk index, and yolk/albumen ratio were significantly greater in white lines than in other evaluated lines of Kurdish quail. Nonetheless, no significant variations between the studied quail lines in yolk height or yolk percentage were identified. These findings are similar to those published in research by Al-Kafajy *et al.,* (2018) who discovered that the yolk weights and yolk index values were significantly influenced by different types of color mutants or quail variations. In agreement with this finding, Hassan *et al.,* (2017) discovered significant (P0.05) differences in yolk height and yolk index among three lines of quail. Ahmed and AL-Barzinji, (2022) indicated that the lines had a significant impact on yolk parameters of three lines of quail The impact of dietary L-carnitine on yolk characteristics (yolk weight, yolk height, yolk diameter, yolk index and yolk/albumen ratio) of three lines of Kurdish quail are presented in Table 6. The addition of L-carnitine to the diet had a significant ($p \leq 0.05$) effect on egg yolk parameters exception of yolk height, yolk diameter and yolk quality index. This result is consistent with the findings of Rabie *et al.,* (1997) and Celik *et al.,*(2004), who reported that adding 50, 100, or 500 ppm of L-carnitine to the diet did not impact on yolk percentage during the later stages of egg production (65 to 73 weeks) in a Hungarian brown hybrid breed. Additionally, these researchers showed that L-carnitine supplementation had no significant effect on yolk index and yolk color score. Kazemi-Fard *et al.,* (2015) did not find any significant impact on egg yolk, yolk color, and yolk quality index in hens fed a diet containing 50 mg/kg of L-carnitine compared to hens on a control diet. The study also found a significant interaction ($p \leq 0.01$) between the addition of LC and lines on yolk weight, yolk diameter, yolk index, and yolk/albumen ratio, while yolk height and yolk percentage were not significantly affected by L-carnitine supplementation. The desert lines fed with a diet containing 350 mg/kg LC had a significant impact on yolk weight (4.60±0.27) and yolk/albumen ratio (63.50±1.36) compared to the other interacted groups. On the other hand, the diameter of the yolk was greater 27.65±0.35 in white lines that were given a diet with 350 mg/kg LC, compared to the Yolk index which showed a consistent value (46.04 ±1.36) in both desert and brown lines that were fed a diet with 550 mg/kg LC at 12 weeks of ages.

3:6: Egg shells and egg surface trait

The results in Table 7 revealed that lines had a significant influence on shell thickness and egg surface area. While, there were no significant variations in shell weight, shell percentage value, and unit surface. This conclusion was consistent with the findings of (Hassan *et al.*, 2017and Ahmed, 2021). Al-Kafajy *et al.,* (2018) detected that the shell thickness and shell weight significantly higher values in the desert and white lines. This observation reverses the findings of Inci *et al.,* (2015) and Chimezie *et al.,* (2017) who suggested that there were no differences in egg shell thickness among the quail lines. However, the statistical examination for this trait indicated that the variances among treatments based on different amounts of L-carnitine supplementation were significantly differ ($p \leq 0.05$) of shell weight, shell thickness and egg surface area but non significantly differed in shell percentage value and unit surface among lines of Kurdish quail. In agreement with Zelaya *et al.,* (2022) showed that supplementation with24 mg /kgm L-carnitine increased egg shell thickness at 90-week-oldof layer hens. Corduk and Sarica, (2008) demonstrated that using 500 mg/kg of L-carnitine improved shell thickness. As reported by Förster and colleagues, (2021) L-carnitine has the potential to alter cellular antioxidant activity when exposed to different pro-oxidant factors. Abad *et al.,* (2021) showed that antioxidant compounds minimize oxidative stress in the gastrointestinal tract (GIT), resulting in a superior productive response and egg quality. As a result, this supplement (L-carnitine) could improve calcium absorption in the intestinal lumen and increase the amount of this mineral (calcite) in the uterus for eggshell development. According to Barret *et al.,* (2019), the decline in shell quality is an indicator associated with the stress of laying hens. While, disagrees with results of Celik *et al.,* (2004) who found that supplementing 50 ppm of L-carnitine in the drinking water at 47-wk-old laying hens for 8 weeks did not have any impact on shell weight and shell thickness. Zhai *et al.,* (2008) discovered that adding L-carnitine to hen diets beginning at hatch had no effect. Furthermore, Kazemi-Fard *et al.,* (2015) concluded that dietary L-carnitine supplementation had no influence on egg shell quality measures such as shell weight and shell thickness. The results of interaction between Line and addition of LC on egg shell quality characteristics of quail noticed a significant difference in each of shell thickness, egg surface area, and unit surface are shown in (Table 6). The white lines fed with a diet containing 350 mg/kg LC was higher in those traits compared to other interacted groups. Furthermore, our investigation identified that L-carnitine supplementation had no impact on shell weight and shell percentage.

Table (7):- L-carnitine, lines, and their interactions' effects on egg shells and egg surface trait of quails.

Traits		Egg Trait				
		Shell weight (g)	Shell percentage (%)	Shell thickness (mm)	Egg surface area	Unit surface
Overall		1.69±0.03	13.19±0.25	0.26±0.01	26.53±0.24	5.46±0.07
Lines (L)						
Desert		1.67±0.04^{a}	12.88±0.42^{a}	0.26±0.01^{ab}	26.51±0.40^{a}	5.40±0.12^{a}
Brown		1.68±0.05^{a}	13.66±0.50^{a}	0.25±0.01^{b}	25.87±0.33^{b}	5.49±0.14^{a}
White		1.72±0.05^{a}	13.02±0.39^{a}	0.27±0.01^{a}	27.23±0.45^{a}	5.50±0.13^{a}
Treatments (T)						
T0= 0%		1.58±0.06^{b}	13.32±0.56^{a}	0.25±0.02^{b}	25.33±0.27^{c}	5.42±0.13^{a}
T1=150%		1.67±0.05^{ab}	13.09±0.50^{a}	0.25±0.01^{b}	26.45±0.46^{bc}	5.36±0.14^{a}
T2= 350%		1.79±0.06^{a}	13.25±0.55^{a}	0.27±0.01^{a}	27.59±0.52^{a}	5.54±0.18^{a}
T3= 550%		1.73±0.05^{ab}	13.09±0.46^{a}	0.26±0.01^{ab}	26.77±0.45^{ab}	5.54±0.14^{a}
Interaction(L∗T)						
Desert	**0%**	1.56±0.12^{a}	13.24±0.89^{a}	0.26±0.02^{b}	25.54±0.28^{ab}	5.51±0.17^{ab}
Desert	**150%**	1.66±0.07^{a}	12.95±1.02^{a}	0.25±0.01^{b}	26.50±0.80^{ab}	5.28±0.20^{ab}
Desert	**350%**	1.72±0.09^{a}	12.65±0.99^{a}	0.26±0.02^{b}	27.67±1.13^{ab}	4.93±0.14^{b}
Desert	**550%**	1.74±0.06^{a}	12.69±0.69^{a}	0.26±0.01^{b}	26.32±0.67^{ab}	5.89±0.23^{a}
Brown	**0%**	1.64±0.12^{a}	14.07±1.04^{a}	0.25±0.01^{b}	24.80±0.34^{abcd}	5.42±0.28^{ab}
Brown	**150%**	1.62±0.11^{a}	13.35±0.97^{a}	0.25±0.01^{b}	25.58±0.55^{cd}	5.55±0.29^{ab}
Brown	**350%**	1.80±0.13^{a}	13.88±1.31^{a}	0.26±0.01^{b}	26.95±0.79^{abcd}	5.74±0.22^{ab}
Brown	**550%**	1.66±0.07^{a}	13.34±0.96^{a}	0.25±0.01^{b}	26.14±0.68^{d}	5.25±0.33^{a}
White	**0%**	1.54±0.12^{a}	12.66±1.06^{a}	0.24±0.01^{b}	25.66±0.68^{bcd}	5.33±0.24^{ab}
White	**150%**	1.72±0.07^{a}	12.96±0.77^{a}	0.26±0.01^{b}	27.26±0.96^{ab}	5.25±0.29^{ab}
White	**350%**	1.84±0.10^{a}	13.22±0.59^{a}	0.30±0.02^{a}	28.15±0.86^{abcd}	5.95±0.36^{a}
White	**550%**	1.78±0.07^{a}	13.23±0.87^{a}	0.26±0.01^{b}	27.84±0.88^{abc}	5.46±0.06^{ab}

$^{a-d}$: Statistically significant differences in both mean values with various superscripts in the same column ($P \leq 0.05$).

4: CONCLUSION

In conclusion, this study was conducted to examine the impact of lines, L-carnitine, and their combination on the laying performance and egg quality parameters. The results revealed that white lines outperformed brown and desert quails in all measured traits. Additionally,the inclusion of a combination of lines and L-carnitine in the diet of Kurdish quails led to predictable improvements in egg weight, egg production, and various egg quality parameters, particularly during the 7-12 week age range. These improvements became more pronounced as the study progressed. As a result, it can be concluded that the optimal concentration of L-carnitine in our experimental conditions was 350 g/kg. Although this level may vary depending on environmental factors and the genotype of the birds.

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