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Original Article

Effect of Supplementation of Diets with L-Carnitine and Methionin on Broiler Chicken Productive Performance

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Abstract

The poultry industry is one of the pillars of food security in the world, as it is relied upon to provide meat and eggs to meet the increasing food demands. Therefore, this study was designed to investigate the effect of L-carnitine and methionine supplementation to the standard diets of broiler chickens in productive performance of broiler (Ross 308). One Hundred- fifty broiler chicks unsexed (Ross 308) with an initial weight with 43 g, were obtained from Al-Habbaniya hatchery (commercial hatchery). The experimental groups were as follows: the animals in T1 group received basal diet without any addition, the animals in T1 group received basal diet supplemented with lead acetate 400 mg/kg feed , the animals in T3 group received diet supplemented with carnitine 300 mg + lead acetate 400 mg, the animals in T4 group received basal diet supplemented with methionine 100 mg + lead acetate 400 mg, the animals in T5 group received basal diet supplemented with methionine 100 mg + carnitine 300 mg + lead acetate 400 mg. Body weight gain and feed consumption were weekly recorded. Feed conversion ratio was also calculated. Results showed that Birds in (T5) fed diets with (carnitine + methionine) observed highest live body weights comparison with T3 (carnitine + lead acetate) and T4 (adding methionine+ lead acetate). Data of results showed no significant differences were recorded in body weight gain. Also, Results obtained increase with feed consumption for treatment T5, while birds in T1 and T4 recorded lowest means in feed consumed. However, birds in T4 and T5 observed best feed conversion ratio as compare with T1, T2 and T3. Therefore, it can conclude that addition carnitine and methionine enhanced broiler productive performance.

Keywords: Carnitine, Methionine, Lead acetate, Broiler, Productive performance

1. Introduction

The poultry industry is one of the pillars of food security in the world, as it is relied upon to provide meat and eggs to meet the increasing food demands. Both chicken eggs and meat have been known as desirable food since their contain high levels of vital protein, good metabolic energy, as well as their short production period, and ease of management (1). Recently, the search began for finding new strategies to improve the productive performance of broiler chickens, such as L-Carnitine and methionine supplementation to the broiler diets. Carnitine is a by-product of the breakdown procedures of the essential amino acids methionine and Rebouche (2), which is referred to as an amino acid for its vital role in the synthesis of several amino acids. Also, carnitine had a biological function in metabolism and oxidation of polyunsaturated fatty acids (3). As well as its antioxidant activity and tissue protection from oxidative damage. Carnitine is also a generator of the essential amino acid methionine and vitamin B6. The great importance of carnitine has been proven in improving the productive performance in poultry (4, 5).

Using natural substances in poultry production with antioxidant activity that do not have negative effects on consumer health, improve the antioxidant system, and protect cell membranes from oxidative damage would be the prefered strategy for improving the production performance in broiler chickens (6, 7).

Therefore, this study was designed to investigate the effect of L-carnitine and methionine supplementation to the standard diets of broiler chickens in productive performance of broiler (Ross 308).

2. Materials and Methods

2.1. Study Design

One Hundred- fifty broiler chicks unsexed (Ross 308) with an initial weight with 43 g, were obtained from Al-Habbaniya hatchery (commercial hatchery). The animals were randomly distributed to five different group (n=50) with three replicates (10 chicks/repeat) placed in 48 floor pens, inside a closed farm containing ground cages with an area of $1\ m^2$. The light-dark cycle used in this study was adjusted to 23 hours light/day from the first day of experiment to the end of the research. The ambient temperature was controlled by thermostat and decreased gradually from 35°C at the first day to 22°C at 21th day of age. Feed were formulated to be meet requirements of bird as guide with all nutrients for broilers as described by Nutrient requirements of poultry guideline (8). Birds were fed a three diets as follows : starter (0-10) days , grower (11-23) days and finisher (24–42) days. Water and feed were provided *ad libitum.* The experimental groups were as follows: the animals in T1 group received basal diet without any addition, the animals in T1 group received basal diet supplemented with lead acetate 400 mg/kg feed , the animals in T3 group received diet supplemented with carnitine 300 mg + lead acetate 400 mg, the animals in T4 group received basal diet supplemented with methionine 100 mg + lead acetate 400 mg, the animals in T5 group received basal diet supplemented with methionine 100 mg + carnitine 300 mg + lead acetate 400 mg.

All the animals were weekly weighed and feed consumption was recorded. Based on recorded measurement data, feed consumption, feed conversion ratio and live body weight gain were calculated during the experiment.

The ingredients and chemical composition of diets were presented in table 1.

Table 1. Ingredient and Chemical composition of experimental diets

Ingredients	10 days-1 Starter	11-23 days Grower	24-42 days Finisher
Yellow corn	29.6	31	33.7
Wheat	29	30.7	32
Soybean 48%	31.5	27.8	23
Protein *	5	5	5
Vegetable oil	2.7	3.5	4.5
Limestone	1.06	1.2	1.2
Di-calcium and phosphate	0.64	0.5	0.3
Methionine	0.23	0.15	0.15
Lysine	0.17	0.14	0.14
Salt	0.1	0.1	0.1
Total	100	100	100
Chemical analysis, Calculated**			
C.P	22.97	21.51	19.58
ME (Kcal / kg feed)	3013	3095	3199
Meth. + Cyst.	1.08	0.98	0.93
Lys.	1.43	1.30	1.17
E.E	5.11	5.97	7.06
fiber	2.85	2.81	2.72
Ca.	0.92	0.88	0.83
Avail. P	0.49	0.42	0.38
L-Arg.	1.15	1.04	0.91
Phosphorus	1.53	1.54	1.54

* Protein concentrate :- 40% CP, 5% Ca,3.8% Methionine, 4.13% Methionine and Cystine, 3.86% Lysine , 4.68% Available Phosphor, ME. 2100 Kcal kg^{-1}, 2.50 mg Sodium, 1.70 mg threonine, 0.43mg Tryptophan, 4.25 mg choline .
**Chemical composition calculated as National Research Council (8)

2.2. Chemicals

The Carnitine was purchased from Vero Universal company (England), The Methionine pure was purchased from Agricultural Research Authority station in Baghdad.

2.3. Statistical Analysis

Statistical analysis of the data of this study was carried out using the steps of the general linear model of the statistical program SAS (9), where the effect of the coefficients for the studied traits was determined using a complete random

design and the differences between means were tested using Duncan (10) 's multinomial test. A significant level of (P<0.05) was implemented.

3. Results

Table 2 showed effect of adding carnitine and methionine to broiler diets. Results of statistical analysis indicated significant differences were observed between different treatments in average weekly body live weight, a significant superiority (P<0.05) for T5 was observed comparison with other treatments, while T1, T2, T3 and T4 did not show any significant differences between them during first week of study, at second weeks, it was noted that superiority for T4 which recorded a significant increase (P<0.05) as comparison with treatments T1, T2 and T3. At third week table 2 shows T5 recorded highest live body weight with (762,66) gm with significant difference comparison with treatments T1, T2 ,T3 and T4. At fourth and fifth weeks T5 recorded significant difference. Results indicated superior increase for T5 comparison with T1, T2, T3 and T4. No significant difference between treatments T1, T2 and T4. While T3 recoded lowest live body weight (2119,13) gm.

Table 3 shows effect of adding carnitine and methionine to broiler diets at different ages on body weight gain. Results indicated significantly differences between treatments in average weekly live body weight gain at 1 week for T5 which recorded highest weights (93,56 gm/bird). Results of second week indicated keeping T5 superior significantly as compare with T1,T2,T3 and T4 which observed significant differences comparison with T1, T2 and T3. Table 3 shows a significant superiority (P<0.05) for T1 comparison with T2 and T4 at 3 week. A significantly differences between treatments were showed for T5 as compare with experimental treatments, while T1, T2, T3 and T4 did not show any significant differences between them at fourth week of study. Also, it was noted from results that T1 recorded a significant increase (P<0.05) as comparison with treatments T2 and T4 during fifth week. Data of sixth week shows significant difference for T2 which recorded highest body weight gain (602,81) gm/bird comparison with treatments T1 and T2, while no significant difference between treatments T1,T3,T5 and T6. A significantly differences not observed between treatments in accumulative live body weight gain . Our finding were agreed with Farhan, Mousa (3) who mentioned that no significant differences between means of body weights gain of broiler fed diets supplemented with carnitine 300 mg/kg feed. On other hand results disagreement with Parsaeimehr, Farhoomand (11); Ardekani, Shevazad (12); Jalali, Rabiei (13) who reported there were significant differences between treatments in body weights gain of broiler fed diets supplemented with carnitine.

As shown in table 4 results of adding carnitine and methionine to broiler diets. At the first week, T1 (basal diet) and T2 (adding lead acetate) observed highest feed consumption with 150,43 and 151,22 gm/bird respectively, while no significant differences between treatments were recorded between T4 (adding of methionine 100 mg/ kg feed + lead acetate 400 mg/kg feed) and T5 (adding of methionine 100 mg/ kg feed with carnitine 300 mg/ kg feed + lead acetate 400 mg/kg feed). In second week of birds age there were a significant increase (P<0.05) in T5, which recorded highest mean of feed consumption compared to other experimental treatments, while T1, T2 and T3 did not indicate significant differences between them. Also, data in table 4 included significant increase (P<0.05) for T1 and T5 which recorded highest feed consumption 602,85 and 617,09 gm/bird respectively, while T2 recorded lowest 543,27 gm/bird at third week . In the fourth week birds of T5 (adding of methionine 100 mg/ kg feed with carnitine 300 mg/ kg feed + lead acetate 400 mg/kg feed) had highest mean of feed consumption as compare with treatments. Results of statistical analysis did not show significant differences between treatments at fifth week. During sixth week of birds age T5 recorded lowest mean feed consumption

1035,48 gm/bird , T2 recorded highest mean feed consumption 1172,23 gm/bird, no significant differences between treatments T1, T3 and T4 which recorded 1093,78, 1117,07 and 1085,21 gm/bird respectively. The accumulative feed conversion coefficient (1-42 days) showed significant differences between treatments T5 observed increase in feed consumption mean 4024,49 gm/bird without significant difference with T2 3954,04 gm/bird. No significant differences between treatments T1 and T4. Results of study were agreed with Jalali, Rabiei (13); El-Wahab, Aziza (14) who demonstrated that addition of 350 mg/kg of carnitine with methionine resulted significant increase (P<0.05) in feed intake as compared with experimental treatments. In contrast, data of results disagreed with Murali, George (15); Farhan, Mousa (3) found that addition of carnitine at 300 mg/kg to broiler diet did not had any effects on feed consumption.

Data of feed conversion ratio are shown in table 5, At the first week, significant differences between treatments were recorded for T4 and T5 which recorded best feed conversion ratio 1,66 and 1,36 (gm feed consumed/gm body weight gain) respectively. Second week a significant decrease (P<0.05) in T1 (basal diet) which recorded worst value of feed conversion coefficient compared to T4 did not differ significantly with T2, T3 and T5. At 21 days of age a significant decrease (P<0.05) for T5 (addition of methionine 100 mg/ kg feed with carnitine 300 mg/ kg feed + lead acetate 400 mg/kg feed) which recorded worst value of feed conversion ratio compared to T2 (addition of lead acetate 400 mg/kg feed) which differs significantly with treatments T1, T3 and T4. Results of statistical analysis did not show significant differences at fourth week between treatments. At fifth week of birds age T1 (basal diet) observed best feed conversion ratio 1,76 compare with T2, T3, T4 and T5 which recorded 2.00, 1.88, 1.88 and 2.03 respectively . Data of sixth week indicated no significant differences between T4 and T5 which recorded highest means compare with T1 and T3 which did not differ significantly between them. While T2 had best values 1,94 gm. feed consumed/gm. live body weight gain. The accumulative feed conversion ratio (1-42 days) showed that no significant differences between T4 and T5 which observed 1,74 and 1,73 respectively while T2 recorded worst feed conversion ratio 1,85 and did not differ significantly with T1.

Table 2. Effect of carnitine and methionine on body weight (gm) of broilers±Standard Error

Treatments	Weeks					
	1	2	3	4	5	6
T1	106,56±4,67^{b*}	244,56±7,11^{d}	625,31±17,96^{cd}	1105,31±28,55^{b}	1698,75±4321^{b}	2208,13±69,72^{ab}
T2	102,19±3,95^{b}	261,25±9,81^{cd}	617,19±19,86^{d}	1106,88±28,51$_{b}$	1639,69±64,61^{b}	2213,13±76,71^{ab}
T3	108,23±2,63^{b}	275,5±6,9^{c}	639,38±11,48^{c}	1121,04±17,34^{b}	1679,48±31,36^{b}	2119,13±42,70^{c}
T4	115,94±4,59^{b}	320,69±9,37^{b}	675,63±19,71^{b}	1150,94±33,32^{b}	1700±55,0^{b}	2173,0±79,51^{b}
T5	136,56±4,86^{a}	365,16±11,17^{a}	762,66±24,31^{a}	1286,41±36,32^{a}	1811,88±45,12^{a}	2257,19±54,62^{a}

* values represent means±standard errors

a, b, c: Different letters within columns indicate significant differences between treatments at a (P≤0.05).

T1: control treatment, T2: addition of lead acetate 400 mg/kg feed, T3: addition of carnitine 300 mg/ kg feed + lead acetate 400 mg/kg feed , T4: addition of methionine 100 mg/ kg feed + lead acetate 400 mg/kg feed , T5: addition of methionine 100 mg/ kg feed with carnitine 300 mg/ kg feed + lead acetate 400 mg/kg feed

Table 3. Effect of carnitine and methionine on live body weight gain (gm) of broilers±Standard Error

Treatments	Weeks						Accumulative 1-6 weeks
	1	2	3	4	5	6	
T1	63,56±4,67^{b} *	138±4,62^{d}	380,75±13,25^{a}	480±17,67^{b}	593,44±23,29^{a}	546,88±33,41^{ab}	2202,63±30,44
T2	59,19±3,95^{b}	159,06±7,22^{c}	355,94±12,95^{b}	489,69±21,28^{b}	532,81±46,51^{b}	602,81±41,26^{a}	2199,5±28,40
T3	65,23±2,63^{b}	167,27±5,24^{c}	363,88±7,71^{ab}	481,67±11,01^{b}	558,44±21,36^{ab}	551,77±22,87^{ab}	2188,26± 39,05
T4	72,94±4,59^{b}	204,75±5,43^{b}	354,94±13,25^{b}	475,31±19,18^{b}	549,06±38,1^{ab}	505,63±42,20^{b}	2162,63±28,98
T5	93,56±4,26^{a}	228,59±7,19^{a}	367,5±14,49^{ab}	523,75±17,56^{a}	525,47±32,06^{b}	470,94±24,9^{b}	2209,81±31,82

* values represent means±standard errors
a, b, c: Different letters within columns indicate significant differences between treatments at a (P≤0.05)
T1: control treatment, T2: addition of lead acetate 400 mg/kg feed, T3: addition of carnitine 300 mg/ kg feed + lead acetate 400 mg/kg feed , T4: addition of methionine 100 mg/ kg feed + lead acetate 400 mg/kg feed , T5: addition of methionine 100 mg/ kg feed with carnitine 300 mg/ kg feed + lead acetate 400 mg/kg feed

Table 4. Effect of carnitine and methionine on feed consumption of broilers±Standard Error

Treatments	Weeks						Accumulative 1-6 weeks
	1	2	3	4	5	6	
T1	150,43±0,28^{a} *	232,98±3,21^{c}	602,85±1,76^{a}	754,25±2,33^{c}	1042,95±1,14	1093,78±18,65^{b}	3877,24±19,27^{c}
T2	151,22±0,41^{a}	240,97±2,96^{c}	543,27±5,52^{c}	779,87±3,2^{b}	1066,5±2,23	1172,23±5,11^{a}	3954,06±7,69^{ab}
T3	141,02±2,03^{ab}	259,21±5,03^{c}	572,65±4,59^{b}	773,06±2,48^{b}	1047,4±3,13	1117,07±8,9^{b}	3910,42±9,77^{b}
T4	121,42±0,42^{b}	303,71±4,29^{b}	571,84±6,76^{b}	785,06±2,37^{b}	1032,75±6,79	1085,21±7,99^{b}	3899,99±15,38^{c}
T5	126,93±1,03^{b}	356,55±7,03^{a}	617,09±11,48^{a}	820,44±8,05^{a}	1068±10,1	1035,48±10,24^{c}	4024,49±12,03^{a}

* values represent means±standard errors
a, b, c: Different letters within columns indicate significant differences between treatments at a (P≤0.05).
T1: control treatment, T2: addition of lead acetate 400 mg/kg feed, T3: addition of carnitine 300 mg/ kg feed + lead acetate 400 mg/kg feed , T4: addition of methionine 100 mg/ kg feed + lead acetate 400 mg/kg feed , T5: addition of methionine 100 mg/ kg feed with carnitine 300 mg/ kg feed + lead acetate 400 mg/kg feed

Table 5. Effect of carnitine and methionine on feed conversion ratio (feed consumed / body weight gain) of broilers±Standard Error

Treatments	Weeks						Accumulative 1-6 weeks
	1	2	3	4	5	6	
T1	2,37±0,18^{a} *	1,69±0,06^{a}	1,58±0,06^{ab}	1,57±0,07	1,76±0,07^{b}	2,00±0,14^{b}	1,83±0,011^{ab}
T2	2,55±0,13^{a}	1,51±0,08^{ab}	1,53±0,05^{b}	1,59±0,08	2,00±1,53^{a}	1,94±0,15^{c}	1,85±0,02^{a}
T3	2,16±0,09^{a}	1,55±0,04^{ab}	1,57±0,03^{ab}	1,60±0,04	1,88±2,18^{a}	2,02±0,09^{b}	1,79±0,017b
T4	1,66±0,09^{b}	1,48±0,04^{b}	1,61±0,06^{ab}	1,65±0,07	1,88±0,36^{a}	2,15±0,19^{a}	1,74±0,011^{c}
T5	1,36±0,06^{b}	1,56±0,05^{ab}	1,68±0,07^{a}	1,57±0,05	2,03±0,38^{a}	2,20±0,12^{a}	1,73±0,017^{c}

* values represent means±standard errors
a, b, c: Different letters within columns indicate significant differences between treatments at a (P≤0.05)
T1: control treatment, T2: addition of lead acetate 400 mg/kg feed, T3: addition of carnitine 300 mg/ kg feed + lead acetate 400 mg/kg feed , T4: addition of methionine 100 mg/ kg feed + lead acetate 400 mg/kg feed , T5: addition of methionine 100 mg/ kg feed with carnitine 300 mg/ kg feed + lead acetate 400 mg/kg feed

4. Discussion

The improvement in body weight of L-carnitine supplementation treatments may be attributed to its role in transporting long-chain fatty acids across the mitochondrial membrane, controlling their oxidation, and its biological effect on energy metabolism (5). Carnitine plays a role in improving the utilization of dietary nitrogen through the availability of the two amino acids (methionine and lysine) from which carnitine is derived to complete the process of protein biosynthesis and other cellular functions (16). Kita, Kato (17) showed a significant superiority in live body weight of broilers during first weeks of study when L-carnitine was added with (50 mg/kg feed). The improvement may be due to L-carnitine increases the concentration of Insulin Growth Factor (IGF-1) and has the ability to increase weight (17). The results of study agreed with the results of Lien and Horng (18), which indicated that adding L-carnitine to broiler diets with (160 mg/kg) had no significant effect on live body weight at 42 days of age. Moreover, agreed with results of El-Wahab, Aziza (14) who reported significant differences in the average live body weight of birds at 42 days of age when carnitine and methionine were added to different energy diets. It also agreed with the results of Murali, George (15) when adding L-carnitine at a concentration (900 mg/kg) to broiler rations. The results of the study were in agreement with the findings of Arslan and Tufan (19) who mentioned that addition carnitine 100/kg feed enhanced growth performance of broiler. The addition of methionine works to balance the representation of amino acids, which leads to a rapid increase in protein synthesis and a reduction in deposited fat. Methionine plays a biological role as intermediate in reactions of methylation and it converted to Cystien which is required Taurine and Glutathione (GSH) for synthesis. Both Taurine and Glutathione peroxidase which considered important compounds in defense system against oxidative stress. Glutathione provides protection against free radicals. However, results of study showed that antioxidant status was influenced by methionine addition (20). Our results were consistent with Jankowski, Ognik (21) who reported that adding methionie to diets enhanced antioxidant status. Xie, Hou (22) mentioned that addition high Methionine levels resulted in high homocysteine levels, which is toxic and results in neurodegenerative disease by impeding endothelium functions and reactive oxygen species generation (23). L-Carnitine is vitamin-like natural, acts in cell as a receptor for activated fatty acids. The major metabolic role of L-Carnitine appears transporting of long-chain fatty acids (LCFA) to inner mitochondrial membrane for oxidation (24). The effects of L-carnitine on growth indicators were inconsistently. Some researchers mentioned useful effects of addition of L-carnitine to broiler diets, while some researchers reported no effects. Carroll and Cote (25) mentioned that carnitine has beneficial effects on animal productive performance by enhance resistant for metabolic diseases, preventing diseases, increase immune system and plays an important role in metabolism and physiological pathways. Moreover, Lettner (26) observed improving in live body weight gain, feed efficiency, decrease in serum triglycerides and cholesterol in broilers fed diets added with carnitine. However, not effect of carnitine on broiler productive performance was adverse in results of some studies (3). Recent studies have suggested that methionine in excess recommendations may result to enhance productive performance, especially body weight gain and feed conversion ratio (27). Carnitine is an endogenous substance that plays as a carrier for long chain fatty acids across through mitochondrial membranes which necessary for β-oxidation and ATP production. Gülçin (28) have demonstrated that carnitine represented a best antioxidant. Also, carnitine play role as scavenger against free radicals such as 1, 1-diphenyl-2-picryl-hydrazyl radical, superoxide anion radical (O:), hydrogen peroxide (OH). Carnitine might interfere with the reactive oxygen species (ROS) formation and chelate metal ferrous ions (28). Moreover, Lee, Lin (29) reported carnitine responsible for buffering fatty acids for exceed acetyl groups

(buffer function) in mitochondria, decreasing mitochondrial free radicals production during hypoxia or substrate excess, especially in tissues.

Authors' Contribution

Study concept and design: A. M. A.
Acquisition of data: A. M. A.
Analysis and interpretation of data: A. M. A.
Drafting of the manuscript: A. M. A.
Critical revision of the manuscript for important intellectual content: A. M. A.
Statistical analysis: A. M. A.
Administrative, technical, and material support: A. M. A.

Ethics

The study design was approved by the ethics committee of the University Of Anbar, Baghdad, Iraq.

Conflict of Interest

The authors declare that they have no conflict of interest.

References

1. Iiasa F. Global agro-ecological zones (gaez v3. 0). IIASA, Laxenburg, Austria and FAO, Rome, Italy. 2012.
2. Rebouche CJ. Carnitine function and requirements during the life cycle. FASEB J. 1992;6(15):3379-86.
3. Farhan OM, Mousa B, AlHamdani AA. EFFECTS OF DIETARY L-CARNITINE TO DIETS WITH DIFFERENT FAT SOURCES ON PRODUCTIVE PERFORMANCE OF BROILER. Plant Arch. 2019;19(2):4409-14.
4. Zhai W, Neuman S, Latour M, Hester P. The effect of in ovo injection of L-carnitine on hatchability of white leghorns. Poult Sci. 2008;87(3):569-72.
5. Arslan C. L-Carnitine and its use as a feed additive in poultry feeding: a review. Rev Med Vet. 2006;157:134-42.
6. Madrigal-Santillán E, Madrigal-Bujaidar E, Álvarez-González I, Sumaya-Martínez MT, Gutiérrez-Salinas J, Bautista M, et al. Review of natural products with hepatoprotective effects. World J Gastroenterol. 2014;20(40):14787.
7. Puvadolpirod S, Thaxton J. Model of physiological stress in chickens 3. Temporal patterns of response. Poult Sci. 2000;79(3):377-82.
8. Council NR. Nutrient requirements of poultry: 1994: National Academies Press; 1994.
9. Cary N. Statistical analysis system, User's guide. Statistical. Version 9. SAS Inst Inc USA. 2012.
10. Duncan DB. Multiple range and multiple F tests. Biometrics. 1955;11(1):1-42.
11. Parsaeimehr K, Farhoomand P, Najafi R. The effects of l-carnitine with animal fat on performance, carcass characteristics and some blood parameters of broiler chickens. Ann Biol Res. 2012;3(7):3663-6.
12. Ardekani HM, Shevazad M, Chamani M, Aminafshar M, Arani ED. The effect of L-carnitine and low crude protein supplemented with crystalline essential amino acids diets on broiler chickens. Ann Biol Res. 2012;3(2):1085-93.
13. JaAnn Biol Resali S, Rabiei R, Kheiri F. Effects of dietary soybean and sunflower oils with and without L-carnitine supplementation on growth performance and blood biochemical parameters of broiler chicks. Arch Anim Breed. 2015;58(2):387-94.
14. El-Wahab A, Aziza A, El-Adl M. Impact of dietary excess methionine and lysine with or without addition of L-carnitine on performance, blood lipid profile and litter quality in broilers. Asian J Anim Vet Adv. 2015;10(5):191-202.
15. Murali P, George S, Ally K, Dipu M. Effect of L-carnitine supplementation on growth performance, nutrient utilization, and nitrogen balance of broilers fed with animal fat. Vet World. 2015;8(4):482.
16. Abd El-Azeem NA, Abdo MS, Madkour M, El-Wardany I. Physiological and histological responses of broiler chicks to in ovo injection with folic acid or l-carnitine during embryogenesis. Growth. 2014;3:4.
17. Kita K, Kato S, Yaman MA, Okumura J, Yokota H. Dietary L-carnitine increases plasma insulin-like growth factor-I concentration in chicks fed a diet with adequate dietary protein level. Br Poult Sci. 2002;43(1):117-21.
18. Lien T, Horng Y. The effect of supplementary dietary L-carnitine on the growth performance, serum components, carcase traits and enzyme activities in relation to fatty acid β-oxidation of broiler chickens. Br Poult Sci. 2001;42(1):92-5.
19. Arslan C, Tufan T. Effects of chitosan oligosaccharides and L-carnitine individually or concurrent supplementation for diets on growth performance, carcass

traits and serum composition of broiler chickens. Rev Med Vet. 2018;169(4/6):130-7.
20. Wang Y, Yin X, Yin D, Lei Z, Mahmood T, Yuan J. Antioxidant response and bioavailability of methionine hydroxy analog relative to DL-methionine in broiler chickens. Anim Nutr. 2019;5(3):241-7.
21. Jankowski J, Ognik K, Kubińska M, Czech A, Juśkiewicz J, Zduńczyk Z. The effect of DL-, L-isomers and DL-hydroxy analog administered at 2 levels as dietary sources of methionine on the metabolic and antioxidant parameters and growth performance of turkeys. Poult Sci. 2017;96(9):3229-38.
22. Xie M, Hou S, Huang W, Fan H. Effect of excess methionine and methionine hydroxy analogue on growth performance and plasma homocysteine of growing Pekin ducks. Poult Sci. 2007;86(9):1995-9.
23. Tyagi N, Moshal KS, Sen U, Vacek TP, Kumar M, Hughes Jr WM, et al. H2S protects against methionine–induced oxidative stress in brain endothelial cells. Antioxid Redox Signal. 2009;11(1):25-33.
24. Fukuda M, Kawabe M, Takehara M, Iwano S, Kuwabara K, Kikuchi C, et al. Carnitine deficiency: Risk factors and incidence in children with epilepsy. Brain Dev. 2015;37(8):790-6.
25. Carroll MC, Cote E. Carnitine: a review. Compendium on Continuing Education for the Practicing Veterinarian. 2001;23(1):45-52.
26. Lettner V. Use of L-carnitine in the broiler ration. Bodenkultur. 1992;43:161-7.
27. Si J, Fritts C, Waldroup P, Burnham D. Effects of excess methionine from meeting needs for total sulfur amino acids on utilization of diets low in crude protein by broiler chicks. J Appl Poult Res. 2004;13(4):579-87.
28. Gülçin İ. Antioxidant and antiradical activities of L-carnitine. Life Sci. 2006;78(8):803-11.
29. Lee B-J, Lin J-S, Lin Y-C, Lin P-T. Effects of L-carnitine supplementation on oxidative stress and antioxidant enzymes activities in patients with coronary artery disease: a randomized, placebo-controlled trial. Nutr J. 2014;13(1):1-7.