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IMMUNO-PHYSIOLOGICAL EFFECTS OF L-CARNITINE ON GROWING RABBITS UNDER HOT ENVIRONMENT IN EGYPT.

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The current study was carried out to investigate the effect of immuno-physiological response of growing rabbits fed L-carnitine under hot environments conditions in Egypt. Total of 60 weaned rabbits (4 wk of age) were divided into four groups (15 in each) with three replicates for each group. Rabbits in all experimental groups were fed the same basal diet (19% CP and 12.5% CF); but differed in L-carnitine content. Rabbits in the 1st group (G1) were fed the basal diet without LC (control). Those in the 2nd (G2), 3rd (G3) and 4th (G4) were fed the basal diet supplemented with LC at levels of 25, 50 and 100 mg/kg diet, respectively. Results revealed that all levels of LC improved (P<0.05) live body weight and total weight gain at different ages (5-8 wk of age), being the highest (P<0.05) in G4 and the lowest in G2. Average feed intake (4-8 wk of age) was higher (P<0.05) in G3 and G4 than in G1, while did not differ in G2 from that in G1. Rabbits in G3 showed the highest (P<0.05) feed intake. All levels of LC improved (P<0.05) feed conversion ratio, being the best in G4 and the poorest in G2 as compared to G1. Concentration of total protein (P<0.01) and globulin (P<0.05) but not albumin increased by increasing LC level up to 100 mg. Rabbits in G3 and G4 groups had significantly increased concentration of glucose (P<0.05) and decreased (P<0.01) cholesterol, LDL and triglycerides concentration, while concentrations of HDL and total lipids were not affected significantly by LC level. Creatinine concentration increased (P<0.01) only in G3 and G4. Activity of transaminases (AST and ALT) was not affected significantly by LC level, while activity of ALP increased (P<0.01) in G4 than in G1. All LC levels reduced (P<0.01) concentration of corticosterone and Na content, and increased (P<0.01) T3 and T4 concentrations as well as K and Cl contents as compared to the control diet. Rabbits fed LC diets had the highest immune response (P<0.01), and viability rate (P<0.05) as well as the lowest (P<0.05) rectal temperature, being the best with 100 mg LC.

In conclusion, dietary L-carnitine supplementation (100 mg/kg diet) after weaning improved growth performance and enhanced subsequent immune responses in rabbits throughout their early growing phase from 4 up to 8 weeks of age.

Keywords: L-carnitine, growth, blood constituents, immunity.

Rabbits are unique among small animals for food and commerce because they produce highly nutritious, low fat, low cholesterol meat rich in proteins and certain vitamins and minerals (Cheeke, 1980).

Recently, the use of some organic substances, possessed to improve the growth performance of animals, through enhancing feed efficiency and immune response. One of these substances is L-carnitine (LC), which naturally acts as B-vitamin-like compound found in human and other animals. It facilitates the transport of long chain fatty acids into mitochondria for energy production (adenosine triphosphate) via β-oxidation and oxidative phosphorylation (Owen *et al.*, 1996).

In addition, LC has been described as a conditionally essential nutrient for human and animals, about 75% of the carnitine source for the body store comes from the diet and the remaining 25% was synthesized in the liver and the kidney from the immediate precursor gamma butyrobetaine. Carnitine in blood is much less concentrated than in tissues. Consequently, carnitine introduced in the diet or synthesized *de novo* in the liver and kidney, must be actively concentrated from the blood into fatty acid metabolizing organs (Maritza *et al.*, 2006).

Torreele *et al.* (1993) noted that LC supplementation may stimulate protein-sparing action by increasing energy derived from lipids and reported that many studies on chickens, pigs, dogs and rats demonstrated a growth improvement by feeding extra dietary LC. The beneficial effects of supplemental LC in the diet on growth performance were indicated in broilers (Rabie, 1997 a&b). Also, supplementation of LC to the diets altered fat metabolism and reduced body fat (Burtle and Liu, 1994) and plays a role in reducing heat stress of broilers and deposition of undesirable fat in market poultry (Celik and Ozturkcan, 2002). Furthermore, LC has an immune-modulatory effect (Cavazza, 1983 and Franceschi *et al.*, 1990).

The aim of the present study was to investigate the effect of supplementing different levels of L-carnitine in the diet on growth performance and immune response of growing rabbits from 4 up to 8 weeks of age.

MATERIALS AND METHODS

This study was conducted at a private rabbit farm in Zian location, located in the north western part of the Nile Delta, Dakahlia Governorate, during the period from August to September 2007. Average minimum and maximum ambient temperatures were 28.87 and 33.28°C, respectively. While, average relative humidity ranged from 60 to 80% during the experimental period.

Temperature-humidity index:

During the whole experimental period, ambient temperature and relative humidity were recorded. According to Livestock and Poultry Heat Stress Indices, suggested by Agricultural Engineering Technology Guide, Clemson University, Clemson, Sc. 29634, USA, using the following formula: THI = db °F-(0.55-0.55 RH) (db-58), Where: db °F=dry bulb temperature in Fahrenheit and RH=relative humidity (%), THI values during the experimental period were almost above 74, indicating that all rabbits were exposed to severe heat stress. However, rectal temperature of growing rabbits was measured only during the final week of the experimental period (7-8 wk of age) at 4 p.m. using digital thermometer.

Experimental groups and feeding system:

Sixty weaned, 4 wk old, New Zealand White (NZW) rabbits, weighing 749.7±1.65g LBW were assigned to four similar experimental groups according to their live body weight, 15 in each (3 replicates of 5 rabbits in each) were used in this study. All rabbits were kept in community battery cages (5 rabbits per cage), set up in an open-sided rabbit house, and managed under similar conditions.

Rabbits in all experimental groups were fed the same basal diet; but differed in L-carnitine content (MEPACO, Egypt). Rabbits in the 1st group (G1) were fed the basal diet without L-carnitine (LC) and served as a control group. Meanwhile, those in the 2nd (G2), 3rd (G3) and 4th (G4) were fed the basal diet supplemented with LC at levels of 25, 50 and 100 mg/kg diet, respectively. The experimental diets were formulated in pelleted form and contained 19% crude protein, 2.5% crude fat, 12.5% crude fiber and 40% nitrogen free extract. Composition of the basal diet is shown in Table 1.

Rabbits in all experimental groups were fed *ad. libitum* and water was available through water nipple in each cage. The experimental period lasted from 4 up to 8 wk of age.

Table 1. Ingredients of the basal diet fed to rabbits in all experimental groups.

Ingredients	%	Ingredient	%
Yellow Corn	6.2	Ground limestone	1.0
Soybean meal, 44%	22.3	Di-calcium phosphate	1.2
Wheat bran	23.4	Common salt	0.5
Barley	15.0	Premix	0.3
Alfalfa hay	30.1	**Total**	**100**

Each 3 Kg premix contains: Vit. A, 12,000,000 IU; Vit. D_3, 3,000,000 IU; Vit. E, 10,0 mg; Vit. K_3, 3,0 mg; Vit. B_1, 200 mg; Vit. B_2, 5,0 mg; Vit. B_6, 3,0 mg; Vit. B_{12}, 15.0 mg; Biotin, 50.0 mg; Folic acid 1,0 mg; Nicotinic acid 35,0 mg; Pantothenic acid 10,0 mg; Mn 80 mg; Cu 8.8 mg; Zn 70 mg; Fe 35 mg; I 1 mg; Co 0.15 mg and Se 0.3 mg.

Experimental procedures:

Live body weight and feed intake were weekly recorded, then body weight gain and feed conversion ratio was calculated at different week intervals of an experimental period from 4 to 8 wk of age. Also, viability rate was calculated at the end of experimental period.

Blood biochemical analysis:

At the end of the experiment (8 wk of age), three rabbits in each experimental group were slaughtered and blood samples were collected into centrifuge tubes without anticoagulant. The serum was separated by centrifugation of blood samples at 4000 rpm for 15 minutes and kept frozen at -20°C till assayed. Concentration of total protein, albumin, total cholesterol, high density lipoprotein (HDL), glucose, creatinine, triglycerides and total lipids, activity of aspartate (AST) and alanine (ALT) transaminases as well as alkaline phosphatase (ALP), concentration of corticosterone, triiodothyronine (T3) and tetraiodothyronine (T4, thyroxine) and mineral contents of Na, K and Cl were determined spectrophotometrically in blood serum using commercial kits according to authors shown in Table 2.

However, concentration of globulin was calculated by subtracting total protein from albumin concentration, while concentration of LDL was calculated by subtracting total cholesterol from HDL concentration.

Determination of antibody titers:

At 6 wk of age, ovine red blood cells (ORBC), a thymus-dependent antigen as a test antigen were used to quantify the specific antibody response as a measure of humoral immune competence. In each treatment group, 2 rabbits were intravenously injected with one ml of 25% ORBC suspension, prepared in 0.9% saline solution. Thereafter, blood samples

Table 2. References of criteria determined in blood serum.

Parameters	Author (s)
Total protein (g/dl)	**Gornall *et al.* (1949)**
Albumin (g/dl)	**Doumas *et al.* (1971)**
Glucose (mg/dl)	**Trinder (1969)**
Total cholesterol (mg/dl)	**Allain *et al.* (1974)**
HDL (mg/dl)	**Myers (1994)**
Creatinine (mg/dl)	**Bauch and Seitz (1985)**
Triglycerides (mg/dl)	**Fossati and Prencipe (1982)**
Total lipids (g/l)	**Frings and Dunn (1970)**
AST and ALT (U/l)	**Reitman and Frankel (1957)**
ALP (U/l)	**Kind and King (1954)**
Corticosterone (ng/l)	**Sainio *et al.* (1988)**
T_3 (ng/ml)	**Sterling (1975)**
T_4 (ng/ml)	**Liewendahl (1990)**
Na and Cl (mEq/l)	**Henry (1974)**
K (mEq/l)	**Tietz (1987)**

were collected, 7 days later, from immunized rabbits in each group and then used to determine the primary antibody response in blood plasma. The determination of antibody titers to ORBC was performed using the microtiter technique according to Trout *et al.* (1996).

Statistical analysis:

The obtained data were statistically analyzed by one way complete design to study the effect of treatment at each time using SAS (2004). However, the significant differences among treatment groups were tested using Multiple Range Test according to Duncan (1955).

RESULTS

Live body weight (LBW) and total weight gain:

Results presented in Table (3) show that all levels of L-carnitine (LC) supplementation significantly ($P<0.01$) improved body weight of growing rabbits at different ages (5-8 wk of age). In a comparison between the treated groups, LBW of rabbits was significantly ($P<0.01$) the heaviest with the highest level of LC (100 mg), the modest with medium LC level (50 mg) and the lightest with the lowest LC level (25 mg). Generally, final LBW of growing rabbits at 8 wk of age significantly ($P<0.01$) increased with diets containing 100, 50 and 25 mg by about 36, 30 and 9% as compared to control group, respectively.

Table 3. Effect of dietary L-carnitine levels on live body weight and total weight gain of growing rabbits at different age intervals (4~8 wk of age).

Items	Experimental group				±MSE
	0 Control	25 mg LC	50 mg LC	100 mg LC	
Live body weight (g) at different ages:					
4 wk	752.0	747.7	748.6	750.3	1.650^{NS}
5 wk	896.7^{d}	949.3^{c}	1069.3^{b}	1125.3^{a}	11.32^{*}
6 wk	1085.3^{d}	1139.7^{c}	1362.0^{b}	1494.0^{a}	17.07^{*}
7 wk	1330.7^{d}	1402.0^{c}	1674.0^{b}	1708.0^{a}	7.800^{*}
8 wk	1455.8^{d}	1585.0^{c}	1894.7^{b}	1976.7^{a}	2.48^{*}
Total weight gain (g) at different age intervals:					
4~5 wk	144.7^{d}	201.7^{c}	320.7^{b}	375.0^{a}	11.44^{*}
5~6 wk	188.7^{c}	190.3^{c}	292.7^{b}	368.7^{a}	17.38^{*}
6~7 wk	245.3^{b}	262.3^{ab}	312.0^{a}	214.0^{b}	19.17^{*}
7~8 wk	121.2^{d}	180.7^{c}	220.7^{b}	268.7^{a}	10.05^{*}
4~8 wk	703.5^{d}	836.8^{c}	1146.0^{b}	1226.3^{a}	12.23^{*}

$^{a.....-d}$: **Means denoted within the same row with different superscripts are significantly different at P≤ 0.05.**

Consequently, the impact of LC levels on total weight gain calculated based on change in LBW at different age intervals was nearly similar to that on LBW, being significantly (P<0.05) the highest with 100 mg LC and the lowest with 25 mg LC at all age intervals (Table 3).

Feed intake and feed conversion ratio:

Results presented in Table (4) show that feed intake during the whole experimental period (4-8 wk of age) was significantly (P<0.05) affected by LC level in diets of growing rabbits, being higher for rabbits fed 100 and 50 mg LC diets than the control group, while those fed 25 mg LC diet did not differ significantly from the controls. It is of interest to note that rabbits in treated groups showed inconsistent trend of differences during all age intervals, but rabbits fed 25 LC diet did not differ than the controls at all age intervals. However, rabbits in 50 mg LC group showed significantly (P<0.05) the highest feed intake during the whole experimental period (4-8 wk of age).

Inspite the conflicted differences in feed intake, all levels of LC significantly (P<0.05) improved feed conversion ratio of growing rabbits, being the best with 100 mg LC and the poorest with 25 mg LC as compared to the controls.

Table 4. Effect of dietary L-carnitine levels on feed intake and feed conversion ratio of growing rabbits at different age intervals (4~8 wk of age).

Items	Experimental group				±MSE
	0 Control	25 mg LC	50 mg LC	100 mg LC	
Feed intake (g/rabbit):					
4~5 wk	415.00^{c}	425.00^{c}	454.34^{b}	507.34^{a}	7.030*
5~6 wk	490.67^{b}	410.00^{b}	640.67^{a}	620.00^{a}	32.70*
6~7 wk	574.33^{a}	534.66^{a}	604.66^{a}	393.33^{b}	37.34*
7~8 wk	251.53^{c}	372.50^{c}	425.33^{b}	495.66^{a}	19.31*
4~8 wk	1742.7^{c}	1742.5^{c}	2125.0^{a}	2016.3^{b}	33.29*
Feed conversion ratio (intake/gain):					
4~5 wk	2.96^{a}	2.14^{b}	1.45^{c}	1.36^{c}	0.080*
5~6 wk	2.62^{a}	2.16^{b}	2.23^{b}	1.69^{c}	0.040*
6~7 wk	2.34^{a}	2.03^{b}	1.93^{c}	1.83^{d}	0.010*
7~8 wk	2.08^{a}	2.06^{a}	1.92^{b}	1.84^{c}	0.007*
4~8 wk	2.47^{a}	2.08^{b}	1.85^{b}	1.64^{c}	0.020*

$^{a, b \text{ and } c}$: Means denoted within the same row with different superscripts are significantly different at $P \leq 0.05$.

The observed improvement in feed conversion ratio of rabbits fed 50 and 100 mg LC was mainly attributed to the significant impact of LC levels on weight gain of rabbits, while in those fed 25 mg LC was due to the tendency of reduction in feed intake and increasing weight gain as compared to the controls (Table 4).

Blood biochemical analysis:

Results in Table (5) revealed that concentration of total protein significantly ($P<0.01$) increased only by increasing LC level up to 100 mg. This increase was associated with significant ($P<0.05$) increase in globulin concentration, not in albumin, which was not insignificantly affected by LC level. On the other hand, only dietary supplementation of LC at level of 50 or 100 mg significantly ($P<0.05$) increased concentration of glucose and decreased ($P<0.01$) cholesterol and LDL concentration, while concentration of HDL was not affected by LC level.

It is worthy noting that the observed reduction in cholesterol concentration of 50 and 100 mg LC groups was associated with significantly ($P<0.01$) marked reduction, in triglycerides and insignificantly in total lipids concentration, as compared to the controls. Finally, creatinine concentration significantly ($P<0.01$) increased only in serum of rabbits fed diets containing 50 and 100 mg LC (Table 5).

Table 5. Effect of dietary L-carnitine level on some biochemical concentrations in blood serum of growing rabbits at the end of the experimental period (8 wk of age).

Parameters	Experimental group				±MSE
	0 Control	25 mg LC	50 mg LC	100 mg LC	
Total protein, g/dl	6.19^{b}	6.37^{b}	6.32^{b}	7.96^{a}	0.13^{**}
Albumin, g/dl	3.66	3.52	3.59	3.99	0.17^{NS}
Globulin, g/dl	2.53^{b}	2.85^{b}	2.73^{b}	3.97^{a}	0.11^{*}
Glucose, mg/dl	114.52^{b}	111.34^{b}	135.15^{a}	167.24^{a}	11.55^{*}
Cholesterol, mg/dl	43.17^{a}	40.63^{a}	25.08^{b}	23.97^{b}	3.17^{**}
HDL, mg/dl	24.25	22.96	20.48	18.86	2.94^{NS}
LDL, mg/dl	18.91^{a}	17.67^{b}	4.59^{b}	5.10^{b}	3.20^{**}
Triglycerides, mg/dl	328.95^{a}	243.72^{b}	227.84^{bc}	208.25^{c}	9.62^{**}
Total lipids, g/l	20.15	19.59	18.45	16.72	1.24^{NS}
Creatinine, mg/dl	22.60^{b}	29.99^{ab}	36.81^{a}	33.04^{a}	2.34^{**}

Means denoted within the same row with different superscripts are significantly different.
^{NS}: Not significant. * Significant at $P \leq 0.05$ ** Significant at $P \leq 0.01$

Enzymatic activity, hormonal concentration and mineral content:

Results in Table (6) show that activity of transaminases (AST and ALT) was not affected by LC level, while activity of ALP significantly ($P<0.01$) increased only by the highest LC level as compared to the control group.

In addition, all dietary supplementations of LC significantly ($P<0.01$) reduced concentration of corticosterone and Na content, and increased T3 and T4 concentrations as well as K and Cl contents compared with the control diet. It is of interest to remarkable that the trend of change in hormonal concentration and mineral content paralleled the level of LC supplementation, whereas rabbits fed the highest LC level (100 mg) showed significantly ($P<0.01$) the lowest corticosterone concentration and Na content as well as the highest T3 and T4 concentrations and, K and Cl contents (Table 6).

Immune response:

Table (7) shows the immunity response of growing rabbits in terms of antibody titer at 6 wk of age and viability rate during the experimental period (4-8 wk of age). Results revealed that rabbits fed LC diets had significantly ($P<0.01$) higher antibody response to ORBC than control rabbits, being significantly ($P<0.01$) higher with 100 mg LC than with 25 and 50 mg LC. Such results were indicated by higher viability rate in all treated groups than in the control one, being significantly ($P<0.05$) the highest only with 100 mg LC (100%), but LC at levels of 25 and 50 mg (80 and 86.7%) did not differ significantly than

Table 6. Effect of dietary L-carnitine level on some enzymatic activity, hormonal concentration and mineral content in serum of growing rabbits at the end of the experimental period (8 wk of age).

Items	Experimental diet				±MSE
	0 Control	25 mg LC	50 mg LC	100 mg LC	
Enzymatic activity (U/l):					
AST	21.00	25.00	40.33	43.33	7.02^{NS}
ALT	20.33	24.33	35.33	37.00	5.43^{NS}
ALP	100.2^{b}	90.0^{b}	120.6^{b}	160.6^{a}	1.13^{**}
Hormonal concentration (ng/ml):					
Corticosterone, ng/l	13.66^{a}	10.66^{b}	9.00^{b}	5.33^{c}	0.58^{**}
T_3, ng/ml	0.67^{d}	1.48^{c}	3.30^{b}	5.00^{a}	0.24^{**}
T_4, ng/ml	5.83^{d}	7.73^{c}	11.26^{b}	15.16^{a}	0.39^{**}
Mineral content (mEq/l):					
Na, mEq/l	169.6^{a}	165.8^{b}	163.1^{c}	159.7^{d}	0.73^{**}
K, mEq/l	4.91^{c}	5.29^{b}	5.17^{b}	7.58^{a}	0.05^{**}
Cl, mEq/l	82.9^{d}	92.6^{c}	105.8^{b}	113.1^{a}	2.24^{**}

Means denoted within the same row with different superscripts are significantly different. ^{NS}: Not significant. ** Significant at $P \leq 0.01$.

Table (7): Effect of dietary L-carnitine level on immune response in term of viability rate (%) and antibody titrer at 6 wk of age.

Items	Experimental diet				±MSE
	0 Control	25 mg LC	50 mg LC	100 mg LC	
Immunity response at 6 wk of age:					
Antibody titer	3.11^{c}	4.19^{b}	4.63^{b}	6.54^{a}	0.10^{**}
Viability rate (%):					
4~8 wk of age	73.3^{b}	80^{b}	86.7^{b}	100^{a}	4.71^{*}
Rectal temperature (°C)					
At the final week	38.92^{a}	38.54^{b}	38.39^{b}	38.32^{b}	0.11^{*}

Means denoted within the same row with different superscripts are significantly different. ^{NS}: Not significant. * Significant at $P \leq 0.05$. ** Significant at $P \leq 0.01$.

the control (73.3%), respectively. In addition, supplementary LC had significant ($P<0.05$) effect on reducing rectal temperature of rabbits in treated groups as compared to the control one (Table 7).

DISCUSSION

The results of the current study showed that dietary LC supplementation at a level of 100 mg significantly improved live body weight and weight gain, which reflected significantly in the best feed conversion ratio of growing rabbits during the experimental period (4-8 wk of age). In agreement with the present results, Newton and Haydon (1988) found that pigs fed up to 6,000 ppm of LC had increased averages of daily gain and feed intake from d 0 to 20 after weaning. Also, Owen *et al.* (1994) found that pigs fed 1,000 ppm LC from d 0 to 35 after weaning were 6% more efficient and were 9% heavier on d 35 compared with pigs fed no added LC. Regarding to growth performance of growing rabbits fed LC diets; some investigators found beneficial effects of dietary LC supplementation on growth performance of layers, young pigs and fish (Torreele *et al.*, 1993, Weeden *et al.*, 1991 and Rabie *et al.*, 1997c). Also, LC supplementation increased body-weight gain and improved feed conversion in weaned pigs (Weeden *et al.*, 1991) and broiler chickens (Von Lettner *et al.*, 1992 and Rabie *et al*, 1997 a&b). However, others did not find significant improvement in growth performance of rabbits (Gabr, 2008) and broilers (Buyse *et al.*, 2001 and Lien and Horng, 2001). The favorable response to LC supplementation in our study is probably due to the increased LC level during the period of rapid growth which confirm and support the previous results in broilers (Rabie and Szilaagy, 1998). Moreover, Rabie *et al.* (1997b) showed that the effectiveness of LC supplementation for improving body weight gain of broilers may depend on the age at which LC is supplemented. Generally, supplemental dietary LC supplementation could improve fatty acid and energy utilization. Therefore, gain and feed efficiency were enhanced, especially in young animals where synthesis is insufficient to meet endogenous requirements (Gropp *et al.*, 1994).

Dietary LC supplementation with the highest level (100 mg) significantly increased total protein concentration in blood serum of growing rabbits, and this increase was most obvious in globulin concentration. The significant increase in globulin concentration was associated with a highest increase in antibody titer in rabbits fed 100 mg LC diet. In this respect, Shug and Gravenstein (1996) mentioned that LC or its precursors stimulates antigenic response in mice (Shug and Gravenstein, 1996). Also, Typlt *et al.* (1991) and Berchiche *et al.* (1994) found that LC stimulates antibody production by murine hybridoma cells.

Concerning the effect of LC on lipid metabolism of growing rabbits, similar results were reported by Abou-Zeid *et al.* (2007), who found that plasma cholesterol, total lipids and triglycerides in broiler chicks significantly decreased with increasing LC level from 0 to 300 mg/kg diet. Also, several researches observed by Lien and Horng (2001); Brandsch and Eder (2002); Xu *et al.* (2003)

and Kim *et al.* (2004) indicated that LC administration led to a decrease of triglycerides and fatty acids stored in the adipose tissue in the form of neutral triglycerides which serves as the body's major fuel storage reserve.

The impact of LC on reducing concentration of total and LDL cholesterol, triglycerides and total lipids in blood serum may be attributed to that LC may affect fatty acid metabolism, which in turn could be affecting key regulatory enzymes involved with acetyl CoA metabolism in the Krebs cycle. Kempen and Odle (1995), using newborn pigs, indicated that L-carnitine influences the flux rate of β-oxidation. If L-carnitine increases fatty acid oxidation, daily lipid accretion rate would be decreased. L-carnitine also may play a part in regulating enzymes such as pyruvate carboxylase and branch-chain keto acid dehydrogenase enzyme. Increased fatty acid oxidation could raise the mitochondrial level of acetyl CoA and pyruvate carboxylase which is an acetyl CoA dependent enzyme that can supply carbon chains for amino acid biosynthesis (Cyr *et al.*, 1991). Generally, the obtained result may suggest that the hypocholesterolemic effect of LC is attributable to an enhanced breakdown of cholesteryl esters. This was indicated by Diaz *et al.* (2000), who reported a similar effect of LC on cholesterol metabolism in the plasma of rabbits fed a high-cholesterol diet.

It is well established that both glycolysis and glucose oxidation are inhibited by high levels of fatty acids. Erfle *et al.* (1971) found an increase in plasma glucose levels in spontaneously ketotic cows that received an i.v. infusion of 80 g of L-carnitine. Although La Count *et al.* (1996 a&b) reported no effect of carnitine on plasma glucose concentrations in dairy cattle regardless of whether LC was fed or infused into the rumen or abomasum. The transient rise in plasma glucose observed in the present study could be due to the high concentration of LC used or the duration of the treatment and/or may be related to decreased fatty acid as affected by LC treatment.

The significant increase in serum creatinine concentration and ALP activity was associated with the best feed conversion ratio for rabbits fed 100 mg LC diet, which may indicate higher protein efficiency of rabbits in these groups. However, supplementary LC had no significant effect on AST and ALT activities in serum of growing rabbits, indicating normal liver function of rabbits in treated groups (Stroev and Makarova 1989). In addition, the obtained reduction in corticosterone concentration in serum of LC treated rabbits may consider as indicator of decreasing the deleterious effects of heat stress rabbits fed LC diets as compared to controls. Similarly, Musser *et al.* (1999) found that LC administration enhanced secretion of hormones, such as insulin and insulin-like growth factor-I. Such finding was indicated by decreasing rectal temperature of rabbits in LC treated groups than control group in our study.

It is of interest to observe that enhanced gain of rabbits fed LC diets was associated with increasing concentration of T3 and T4 in blood serum indicating higher energy supply for treated rabbits and elimination of heat stress by elevating concentration of these hormones under heat stress condition. In agreement with the present results, Musser *et al.* (1999) found that LC administration enhanced secretion of T3 hormone. Decreasing Na and increasing K and Cl contents in rabbits fed LC diets as compared to the controls may be related to the effect of the hot thermal condition on excretion of minerals in urine rather than the effect of supplementary LC in diets of rabbits.

In conclusion, dietary L-carnitine supplementation (100 mg/ kg diet) after weaning improved growth performance and enhanced subsequent immune responses in rabbits throughout their early growing phase from 4 up to 8 wk of age.

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التأثيرات المناعية والفسيولوجية للكارنتين من الصورة L علي الأرانب النامية المرباة تحت ظروف البيئة المصرية الحارة

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أجريت الدراسة الحالية لدراسة تأثير الاستجابة المناعية والفسيولوجية للأرانب النامية المرباه تحت ظروف الإجهاد الحراري في مصر. استخدم في هذه التجربة ٦٠ أرنب في عمر الفطام (عند عمر ٤ أسابيع) وقسمت إلى أربع مجموعات (١٥ في كل مجموعة) وتم تقسيم كل مجموعة إلي ثلاث مكررات. الأرانب في جميع المجموعات التجريبية تم تغذيتها علي عليقة محتوية علي (١٩ ٪ بروتين ، ١٢.٥ ٪ ألياف) ، ولكن اختلف محتوي العليقة من الكارنتين من الصورة L. الأرانب في المجموعة الأولي تم تغذيتها علي العليقة الخالية من الكارنتين. الأرانب بالمجموعة الثانية والثالثة والرابعة تم تغذيتها علي علائق محتوية علي ٢٥-٥٠-١٠٠ ملليجم/كجم عليقة كارنتين من الصورة L على التوالي. أظهرت النتائج أن جميع المستويات من الكارنتين من الصورة L عند مستوي معنوية (٠.٠٥) حسنت معنوياً وزن الجسم والزيادة المكتسبة في الوزن عند الأعمار المختلفة (٥-٨ أسابيع من العمر) ولكن الزيادة كانت معنوية في المجموعة الرابعة عن المجموعة الثانية. متوسطات الغذاء المأكول ارتفع معنويا عند مستوي (٠.٠٥) في المجموعة الثالثة والرابعة عن المجموعة الأولي ولم يختلف معنوياً في المجموعة الثانية والأولي. الأرانب بالمجموعة الثالثة أظهرت أعلي كمية غذاء مأكول.

جميع مستويات الكارنتين من الصورة L حسنت معنوياً عند مستوي (٠.٠٥) معدل التحويل الغذائي ولكن معدل التحويل الغذائي في المجموعة الرابعة أفضل من المجموعة الثانية والأولي. تركيز البروتينات الكلية عند مستوي معنوية (٠.٠١) والجلوبيولين عند مستوي (٠.٠٥) وليس الأبيومين زادت بزيادة مستويات الكارنتين. الأرانب بالمجموعة الثالثة والرابعة أظهرت زيادة معنوية في تركيز الجلوكوز عند مستوي (٠.٠٥) وأظهرت إنخفاض معنوي عند مستوي معنوية (٠.٠١) في تركيز كلاً من الكوليسترول والبروتينات الدهنية المنخفضة الكثافة وكذلك الجليسريدات الثلاثية، بينما تركيز البروتينات الدهنية عالية الكثافة واللبيدات الكلية لم تتأثر معنويا بمستويات الكارنتين من الصورة L. تركيز الكيرياتينين زادت معنويا عند مستوي معنوية (٠.٠١) فقط في المجموعة الثالثة والمجموعة الرابعة. كفاءة إنزيمات الكبد AST و ALT لم تتأثر معنوياً بإضافة مستويات الكارنتين من الصورة L بينما كفاءة الألكلين فوسفاتيز زادت معنوياً عند مستوي (٠.٠١) في المجموعة الرابعة عنه في المجموعة الأولي. جميع مستويات الكارنتين من الصورة L عند مستوي معنوية (٠.٠١) خفضت معنوياً تركيز هرمون الكورتيكوستيرون والصوديوم وأدت إلي زيادة تركيز هرمون التراي أيودوثيرونين والثيروكسين عند مستوي معنوية (٠.٠١) وكذلك تركيز كلاً من البوتاسيوم والكلوريد مقارنة بعليقة الكنترول. الأرانب التي تم تغذيتها علي علائق الكارنتين أظهرت تحسناً معنوياً في الاستجابة المناعية عند مستوي معنوية (٠.٠١)، وكذلك معدل الحيوية عند مستوي معنوية (٠.٠٥) وكذلك أظهرت إنخفاض ملحوظ في درجة حرارة المستقيم وكانت أفضل المقاييس عند استخدام معدل ١٠٠ ملليجم/كجم عليقة من الكارنتين من الصورة L.

أظهرت النتائج أن إضافة الكارنتين من الصورة L بمعدل (١٠٠ ملليجم/كجم عليقة) بعد الفطام حسنت معنوياً معدل الأداء الإنتاجي وحسنت معدل الاستجابة المناعية في الأرانب النامية في المراحل العمرية المبكرة من عمر ٤-٨ أسابيع من العمر.