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Study the Effects of Different Levels of Fat and L-carnitine on Performance, Carcass Characteristics and Serum Composition of Broiler Chicks

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Abstract: An experiment was conducted in order to study the effect of 3 levels of fat (1, 3, 5%) and 2 levels of L-carnitine (0 and 250 mg kg^{-1}) on 360 male Ross broiler chicks in a factorial arrangement (2×3) with completely randomized design with 6 treatments, 4 replicates and 15 chicks in each replicates. All diets were isocaloric and isonitrogenous and were fed to chicks from 1 to 42 days of ages. During the experiment feed intake, body weight gain and feed conversion ratio were measured weekly. Mortality was measured throughout the experiment. At 42 days of ages 4 birds from each treatment were slaughtered for determination of carcass characteristics and serum composition. Data of the experiment were analyzed by GLM procedure of SAS. Increasing of fat in the diets significantly improved performance of chicks in grower (22 to 42 days) and whole period (1 to 42 days) of the experiment ($p<0.05$). Chicks fed with diets containing 3% fat had the highest breast meat and lowest abdominal fat percentage ($p<0.05$). Adding L-carnitine to diets had not significant effect on performance and carcass characteristics. Interaction between fat and L-carnitine was significant on liver weight ($p<0.05$). The levels of triglyceride (TG) and glucose in blood serum were affected by increasing of dietary fat ($p<0.05$). Adding L-carnitine to diets significantly decreased the level of serum triglyceride, cholesterol and VLDL ($p<0.05$). Dietary treatments had not significant effect on mortality.

Key words: Fat, L-carnitine, broiler, performance, breast meat, serum composition

INTRODUCTION

Excessive carcass fat accumulation, particularly in the abdominal and visceral areas, is one of the major concerns for broiler producers. This fat is generally undesirable for consumers and represents a waste product to the poultry processor. Numerous attempts have been made to minimize this fat accumulation, either genetically or by dietary manipulation, with different degrees of success. Dietary L-carnitine could play a role in reducing the undesirable fat in carcasses of broiler (Rabie *et al*., 1997b; Rabie and Szilagyi, 1998).

L-carnitine (β-hydroxy γ-trimethylaminobutyrate) is a water-soluble quaternary amine that exists naturally in micro-organisms, plants and animals and is required for the long chain fatty acid transfer from cytoplasm to mitochondrial matrix for subsequent β-oxidation and energy production (Bremer, 1983). Plants and plant-based feedstuffs generally contain very little carnitine compared with animals (Baumgartner and Blum, 1993, 1997). The concentration of carnitine in animals varies widely across species, tissue type and nutritional status of the animal (Rabie *et al*., 1997b). L-Carnitine is biosynthesized in vivo from lysine and methionine (Rebouche and Paulson, 1986) in the presence of ferrous ions and 3 vitamins, ascorbate, niacin and pyridoxine that are required as cofactors for the enzymes involved in the metabolic pathway of L-carnitine (Bieber, 1988; Feller and Rudman, 1988; Rebouche, 1991). Studies with broiler chickens have shown that supplemental dietary L-carnitine increases body weight gain, improves feed conversion ratio and reduces abdominal fat content (Owen *et al*., 2001; Rabie *et al*., 1997b; Rabie and Szilagyi, 1998). Additionary, carnitine may modulate immune function as evidenced by enhanced antibody response in L-carnitine supplemented broiler chickens (Mast *et al*., 2000) and

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pigeons (Janssens *et al*., 2000). Dietary supplemental carnitine studies on poultry have mostly focused on broilers; since L-carnitine was demonstrated to have beneficial effects on broilers under stressful conditions, it has been accepted as a potential protecting agent for broilers in the case of stress induced by high environmental temperatures (Celik *et al*., 2003). However, there are contradictory studies in which dietary L-carnitine supplementation did not affect growth performance, abdominal fat content and some internal organ weights (Barker and Sell, 1994; Leibetseder, 1995; Sarica *et al*., 2005; Deng *et al*., 2006). The aim of the present study was to investigate the effects of supplementary L-carnitine in diets with different levels of vegetable fat on performance, carcass characteristics and serum composition of Ross 308 male broiler chicks.

MATERIALS AND METHODS

In a factorial arrangement with 3 levels of soy oil (1, 3, 5 %) and 2 levels of L-carnitine (0 and 250 mg kg^{-1}), three hundreds and sixty, one-day old Ross 308 male broiler chicks were randomly distributed in 24 pen with 15 chicks in each pens. This experiment was carried out in a local poultry farm in Mashhad in summer 2004. The chicks were kept in litter pens under uniform environmental condition from hatch until 6 week of age. Temperature was kept 32°C for the first week and reduced 3°C weekly thereafter. A continuous lighting program was provided during the experiment. Diets were formulated by using of UFFDA software. All diets were isocaloric and isonitrogenous. Prior to experimental diets formulation, feed ingredients were analyzed for their moisture, CP, EE, CF and ash (AOAC, 1984). The main ingredients in diets were corn, soybean meal and fish meal. Experimental diets were fed from 1 to 42 days of age. Starter and grower diets were fed from 1 to 21 and 21 to 42 days of age respectively. The ingredients percentage and chemical composition of in starter and grower periods are shown in Table 1. Feed and water were provided *ad-libitum* during the entire experimental period. During the experiment feed intake, body weight gain, feed conversion ratio were measured weekly. Mortality was measured throughout the experiment. In day 42, one chick from each pen, with body weight similar to pen average body weight, was selected and slaughtered to determine carcass, breast meat, abdominal fat, heart, liver weight and percentage. Feed and water were withdrawal 12 and 4 h respectively before slaughtering. For determination of TG, cholesterol, VLDL, glucose, LDL, HDL, 10 mL of blood were taken from wing vein of each bird in each unit. There were 6 (3 levels of fat and 2 levels of L-carnitine) treatments and 4 replicates with 15 chicks in each replicate. Data from this experiment were analyzed using the General Linear Model (GLM) procedure of SAS (SAS Institute, 1998). When differences among means were found, means were separated using Duncan's multiple ranges test at $p<0.05$ (Steel and Torrie, 1980).

Table 1: Composition of diets used in starter (1-21 days) and grower period (22-42 days) (%)

	Starter			Grower		
Ingredients	1	2	3	1	2	3
Corn	60.30	54.98	49.77	65.96	60.14	54.30
Soybean meal	33.00	34.02	35.02	28.94	30.06	31.19
Fish meal	1.80	1.80	1.80	0.00	0.00	0.00
Soy oil	1.00	3.00	5.00	1.00	3.00	5.00
Limestone	1.20	1.20	1.20	1.33	1.32	1.31
Dicalcium phosphate	1.16	1.12	1.13	1.05	1.06	1.07
Vitamin premix[1]	0.25	0.25	0.25	0.25	0.25	0.25
Mineral premix[2]	0.25	0.25	0.25	0.25	0.25	0.25
Vitamin E	0.10	0.10	0.10	0.10	0.10	0.10
Salt	0.30	0.30	0.30	0.25	0.25	0.25
Methionie	0.11	0.11	0.12	0.05	0.06	0.06
L-carnitine	+	+	+	+	+	+
Total	100.00	100	100.00	100.00	100.00	100.00
Composition (%)						
ME_n (kcal kg^{-1})	2878.00	2878.00	2878.00	2940.00	2940.00	2940.00
CP	20.72	20.72	20.72	18.34	18.34	18.34
Ca	0.89	0.89	0.89	0.82	0.82	0.82
Available Phosphorus	0.39	0.39	0.39	0.32	0.32	0.32
Methionie+Cystine	0.78	0.78	0.78	0.65	0.65	0.65
Methionine	0.45	0.45	0.45	0.35	0.35	0.35
Lysine	1.12	1.12	1.12	0.95	0.95	0.95
Arginine	1.33	1.33	1.33	1.15	1.15	1.15

[1]Supplied per kilogram of diet: 6050 μg vitamin A (retinyl acetate+retinyl palmitate), 55 μg vitamin D_3, 22.05 μg vitamin E (dl-α-topheryl acetate), 2.0 mg K_3, 5 mg B_1, 6.0 mg vitamin B_2, 60 mg vitamin B_3, 4 mg vitamin B_6, 0.02 mg vitamin B_{12}, 10.0 mg pantothenic acid, 6.0 mg folic acid, 0.15 mg biotin, 0.625 mg ethoxyquin. [2]Suppled per kilogram of diet: 500 mg CaCO3, 80 mg Fe, 80 mg Zn, 80 mg Mn, 10 mg Cu, 0.8 mg I, 0.3 mg Se

RESULTS AND DISCUSSION

The effects of dietary fat supplementation at different levels on feed intake, body weight gain and Feed Conversion Ratio (FCR) of broiler chicks in starter, grower and whole periods of the experiment are summarized in Table 2 and 3. Effects of fat on feed intake was significant in all periods of the experiment ($p<0.05$). With increasing the level of fat in diets feed intake increased. Broiler fed with diets containing 5% fat consumed the most feed in all phases of the experiment. Supplemental fats increase the palatability of the diet and reduced the dustiness of the feed, thus the feed intake can be increased (Bisplinghoff, 1992; Wiseman and Salvdor, 1991). Addition of fat to diets increased body weight gain and improved FCR in grower and whole period of the experiment ($p<0.05$). Chicks fed with diets containing 3 or 5% fat had the most body weight gain and best value for FCR. There were not significant differences between treatments containing 3 and 5% fat for these traits and therefore, the optimum level of supplemental fat in broiler diets was 3% on basis of the situation of the present study. Diet fat *per se* can affect rate of passage of digesta and this can influence overall diet digestibility. Delay rate of passage suggests that digesta spends more time in contact with digestive enzymes, carriers or co-factors and absorptive sites, therefore addition of fat to the diet may increase digestion of non-fat components of the diets (Mateos and Sell, 1981; Sell *et al*., 1986). These findings are in agreement with results of previous studies (Lien and Horng, 2001; Xu *et al*., 2003). The effects of different levels of fat on carcass traits are shown in Table 4. Dietary fat also had significant effect on breast meat percentage and fat content of breast meat ($p<0.05$). Increasing the level of fat in diets from 1-3 or 5% improved breast meat yield ($p<0.05$). It may be related to increasing the fat content of breast meat. With increasing the level of fat from 1-3 or 5% in diets the fat content of breast meat significantly increased too ($p<0.05$). The results are in agreement with the findings of the other researchers (Ajuyah *et al*., 1991; Cortinase *et al*., 2004). Effect of dietary fat was significant on abdominal fat and liver weight percentage ($p<0.05$). There were significant differences between treatments containing 1 and 3% and between diets containing 3 and 5% fat for this trait. With increasing dietary fat, more energy was available for the chicks and it is stored in adipose tissues and as abdominal fat. The effects of L-carnitine supplementation at different levels on feed intake, gain and FCR of broiler chicks at different phases of the experiment are presented in Table 5. Adding L-carnitine to diets had not significant effect on feed intake, body weight gain and FCR in all phases of the experiment ($p>0.05$). These results are in agreement with findings of the previous studies (Leibetseder, 1995; Buyse *et al*., 2001). Cartwright (1986) reported that growth performance of broilers, in terms of body weight and feed intake, was not affected by feeding diet supplemented with 0.05% L-carnitine of the diet from 5 to 7 weeks of age. Barker and Sell (1994) also reported that the supplementation of dietary L-carnitine at 0, 50, or 100 mg kg^{-1} diet did not affect body weight gain, feed intake, or feed efficiency of broiler chickens and young turkeys fed low- or high-fat diets. Likewise, Leibetseder (1995) pointed out that body weight gain and feed conversion ratio of broiler chickens were not influenced by dietary carnitine at 200 mg kg^{-1}. The dietary addition of 100 mg kg^{-1} L-carnitine did not affect body weight gain, feed intake, or feed efficiency of broilers (Buyes *et al*., 2001). Lien and Horng (2001) noticed that feeding diets supplemented with 0 and 160 mg of L-carnitine kg^{-1} did not significantly affect the performance of broiler chickens. Xu *et al*. (2003) observed no differences in body weight gain, feed intake, or FCR of from 20 to 60 mg kg^{-1} tended to improve growth

Table 2: Effect of different levels of fat on performance of broiler chicks in starter and grower periods

	Period							
	Starter (1-21 days)				Grower (21-42 days)			
Fat (%)	1	3	5	SEM	1	3	5	SEM
Feed intake (g)	848.7^{b}	850.2^{ab}	857.5^{a}	9.74	2744.1^{b}	2750.5^{b}	2766.2^{a}	42.86
Gain (g)	560.3	560.3	563.0	3.95	1385.2^{b}	1408.3^{a}	1411.8^{a}	28.83
FCR (g:g)	1.514	1.517	1.523	0.025	1.980^{a}	1.952^{b}	1.959^{b}	0.017

Means with different superscript(s) in each rows differ significantly ($p<0.05$)

Table 3: Effect of different levels of fat on performance of broiler chicks in whole period (1-42 days) of the experiment

	Period			
	(1-42 days)			
Fat (%)	1	3	5	SEM
Feed intake (g)	3592.8^{b}	3600.7^{b}	3623.7^{a}	45.00
Gain (g)	1945.6^{b}	1968.7^{a}	1974.8^{a}	29.46
FCR (g:g)	1.846^{a}	1.828^{b}	1.834^{b}	0.013

Means with different superscript(s) in each rows differ significantly ($p<0.05$)

Table 4: Effect of different levels of fat on carcass characteristics of broiler chicks

	Fat (%)			
Carcass characteristics	1	3	5	SEM
Breast meat (%)	14.92[b]	17.54[a]	16.96[a]	0.35
Fat content of breast meat (%)	0.516[b]	1.366[a]	1.637[a]	0.116
Abdominal fat (%)	1.74[a]	0.79[b]	1.80[a]	0.11
Relative liver weight (%)	2.213[b]	2.590[a]	2.613[a]	0.10
Relative heart weight (%)	0.385	0.360	0.357	0.015

Means with different superscript(s) in each rows differ significantly ($p<0.05$)

Table 5: Effect of different levels of L-carnitine on performance of broiler chicks

	Period								
	Starter (1-21 days)			Grower (21-42 days)			Whole period (1-42 days)		
Carnitine (mg kg^{-1})	0	250	SEM	0	250	SEM	0	250	SEM
Feed intake (g)	852.90	851.40	7.950	2753.90	2753.30	35.00	3606.80	3604.70	36.74
Gain (g)	561.90	560.50	3.220	1400.10	1403.50	23.54	1962.00	1964.00	24.06
FCR (g:g)	1.51	1.51	0.021	1.96	1.96	0.014	1.83	1.83	0.010

Means with different superscript(s) in each rows differ significantly ($p<0.05$)

Table 6: Effect of different levels of L-carnitine on carcass characteristics of broiler chicks

L-carnitine (mg kg^{-1})	0	250	SEM
Breast meat (%)	16.14	16.81	0.28
Fat content of breast meat (%)	1.27	1.07	0.094
Abdominal fat (%)	1.57	1.32	0.09
Relative liver weight (%)	2.489	2.455	0.08
Relative heart weight (%)	0.368	0.366	0.012

male broilers fed diet supplemented with 0, 25, 50, 75, or 100 mg kg^{-1} L-carnitine. However, Lettner *et al.* (1992) showed that dietary supplementation with L-carnitine performance of broiler chickens. Rabie *et al.* (1997b) indicated that the supplementation of dietary L-carnitine at 3 levels (50, 100, or 150 mg kg^{-1}) to a basal diet significantly increased body weight gain of broiler chickens compared with those of broilers fed the basal diet. The discrepancies between studies may result from different levels of L-carnitine supplementation, ingredients and metabolizable energy, methionine and lysine levels of diets, sex and physiological status of the animals. The calculated methionine and lysine (the precursors of L-carnitine) levels in the present experimental diets were sufficient for broiler chicks according to the nutrient requirements established by the National Research Council (NRC, 1994)

The effects of different levels of L-carnitine on carcass traits of broiler chicks are shown in Table 6. Adding L-carnitine had not significant effect on breast meat yield and liver and heart weights. These findings are in agreement with results of other experiments (Barker and Sell, 1994; Leibetseder, 1995; Sarica *et al.* 2005; Deng *et al.*, 2006). Likewise, Celik *et al.* (2003) indicated that supplementary carnitine did not influence carcass weight, carcass yield, or relative weight of abdominal fat in broiler chickens. Due to increasing the oxidation of fats, adding L-carnitine to diets trend to have a significant effect in lowering (1.32 vs 1.57%) abdominal fat ($p<0.07$). It also reduced the fat percentage of breast meat (1.07 vs 1.27%). The fat-lowering effect of dietary L-carnitine obtained in the present study may be explained, at least partly, by a reduction in hepatic lipogenic capacity, since liver is the major site of lipogenesis in poultry, but other factors may be also responsible for the regulation of the rate of fat accumulation in adipose tissue. This may imply that abdominal fat is the most susceptible component of a broiler carcass for alternation by dietary L-carnitine. Rabie and Szilagyi (1998) and Xu *et al.* (2003) reported that the abdominal fat percentage of body weight was significantly reduced by adding L-carnitine to diets. Conversely, other studies with poultry have been shown that abdominal fat did not affected by adding dietary L-carnitine (Barker and Sell, 1994; Cartwright, 1986). Cartwright (1986) observed no significant effect on abdominal fat when L-carnitine was fed at 0.05% of the diet from 5 to 7 weeks of age. Barker and Sell (1994) reported that addition of L-carnitine to the diet (50 or 100 mg kg^{-1}) did not influence abdominal fat weight of broiler chickens fed low- or high-fat diets. Leibetseder (1995) also reported that abdominal fat content of broilers was not affected by dietary carnitinet 200 mg kg^{-1} of diet. Rabie *et al.* (1997a, b) pointed out that supplementary carnitine did not significantly affect live body weight or the relative weights of liver, heart and gizzard, except abdominal fat pad weights. Daskiran and Teeter (2001) observed no significant effect in dressing percentage and abdominal fat pad contents of broilers in response to dietary L-carnitine supplementation. Xu *et al.* (2003) showed that crude fat content in breast muscle of male broilers is significantly increased by supplementing with 50 or 75 mg of L-carnitine kg^{-1} of diet.

Table 7: Effect of different levels of fat and L-carnitine on performance of broiler chicks (1-42 days)

Carnitine (mg kg^{-1})	0			250			
Fat (%)	1	3	5	1	3	5	SEM
Feed intake(g)	3588.2^{e}	3606.2^{abc}	3626.0^{a}	3579.5^{abc}	3595.2^{bc}	3621.5^{ab}	25.98
Gain (g)	1942.7^{b}	1968.0^{a}	1975.5^{a}	1948.0^{b}	1969.5^{a}	1974.2^{a}	17.01
FCR (g:g)	1.847^{a}	1.832^{bc}	1.835^{b}	1.846^{a}	1.825^{c}	1.834^{bc}	0.007

Means with different superscript(s) in each rows differ significantly ($p<0.05$)

Table 8: Effect of different levels of fat and L-carnitine on carcass characteristics of broiler chicks (% live weight)

L-carnitine (mg kg^{-1})	0			250			
Fat (%)	1	3	5	1	3	5	SEM
Breast meat	15.02^{c}	17.05^{ab}	16.35^{bc}	14.82^{c}	18.03^{a}	17.59^{ab}	0.2
Brest meat fat	0.58^{c}	1.64^{a}	1.59^{a}	0.45^{c}	1.09^{b}	1.68^{a}	0.06
Abdominal fat	1.94^{a}	0.91^{b}	1.86^{a}	1.52^{a}	0.68^{b}	1.75^{a}	0.06
Liver weight	2.12^{c}	2.85^{a}	2.95^{abc}	2.30^{cb}	2.33^{cb}	2.73^{ab}	0.06
Heart weight	0.39^{a}	0.36^{a}	0.35^{a}	0.37^{a}	0.36^{a}	0.36^{a}	0.008

Means with different superscripts in each rows differ significantly ($p<0.05$)

Table 9: Effect of different levels of fat and L-carnitine on blood serum composition of broiler chicks (mg dL^{-1})

L-carnitine (mg kg^{-1})	0			250			
Fat (%)	1	3	5	1	3	5	SEM
TG	63.25^{b}	76.00^{a}	61.25^{b}	64.00^{b}	56.50^{b}	53.50^{b}	3.41
Cholesterol	147.50^{a}	148.50^{a}	137.25^{a}	109.75^{b}	139.00^{a}	136.50^{a}	8.67
VLDL	12.750^{b}	15.25^{a}	10.75^{b}	12.50^{b}	12.00^{b}	10.50^{b}	0.70
LDL	79.25a^{b}	85.50^{a}	72.00^{ab}	44.75^{b}	82.50^{ab}	79.00^{ab}	11.63
HDL	55.25^{a}	58.00^{a}	53.50^{a}	59.75^{a}	54.25^{a}	58.75^{a}	3.40
Glucose	135.00^{b}	152.25^{b}	167.75^{a}	154.25^{ab}	108.75^{c}	170.75^{a}	9.27

Means with different superscript(s) in each rows differ significantly ($p<0.05$)

Interaction of different levels of fat and L-carnitine on feed intake, gain, FCR are summarized in Table 7. Interaction of fat and L-carnitine had not significant effect on above traits ($p>0.05$). Interaction of fat and L-carnitine on carcass traits are shown in Table 8. The levels of TG and glucose in blood serum were affected by increasing dietary fat. There was significant difference between treatments containing 3 and 5% fat for serum TG. Increasing the level of serum glucose in chicks fed with diets containing 5% fat probably related to glycerol content of TG, which converted to glucose via gluconeogenesis pathway. Adding L-carnitine to diets significantly decreased the level of serum TG, cholesterol and VLDL ($p<0.05$). Decreasing the level of serum TG in chicks fed with diets supplemented with L-carnitine probably related to increasing oxidation of fatty acids. With increasing the transportation capacity of fatty acids to inner mitochondrial membrane, the serum TG level was reduced. L-carnitine supplementation to diets containing high level of fat, increases oxidation of fatty acids and reduces the secretion of VLDL in liver, thus the level of serum VLDL reduces. The results are in agreement with the previous findings (Lien and Horng, 2001; Xu *et al*., 2003). Interaction of fat and L-carnitine on blood serum components are presented in Table 9. Interaction between fat and L-carnitine on serum TG and glucose was significant ($p<0.05$). In general use of 3% vegetable oil in this experiment caused the best performance in male broiler chicks and under the condition of this experiment, adding 250 mg kg^{-1} L-carnitine to broiler diets in some extend reduced abdominal fat percentage. The effectiveness of supplemental dietary L-carnitine for increasing performance and carcass characteristics may be depend on condition which L-carnitine is added. Results of the present experiment showed positive effect of fat on performance and the significant effect of L-carnitine on decreasing the levels of serum TG, cholesterol and VLDL. For future researches, use of L-carnitiune in broiler diets without rich sources of carnitine (fish meal) containing high level of fat and also with feed restriction status are recommended.

REFERENCES

Ajuyah, A.O., K.H. Lee, R.T. Hardin and J.S. Sim, 1991. Changes in the yield and in the fatty acid composition of whole carcass and selected meat portions of broiler chickens as full-fat oil seeds. Poult. Sci., 70: 2304-2314.

Association of Official Analytical Chemists, 1984. Official Methods of Analysis. 14th Edn., Williams, S. (Ed.), AOAC, Arlington, Virginia.

Barker, D.L. and J.L. Sell, 1994. Dietary carnitine did not influence performance and carcass composition of broiler chickens and young turkeys fed low or high-fat diets. Poult. Sci., 73: 281-287.

Baumgartner, M. and R. Blum, 1993. L-carnitine in Animalnutrition. In: Vitamine Und Weitere Zusatzstoffe Bei Mensch Und Tier (Vitamins and Other Supplements for Humans and Animals). Flachowsky, G. and R. Schubert (Eds.), Friedrich-Schiller Univ., Jena, Germany, pp: 413-418

Baumgartner, M. and R. Blum, 1997. Typical L-carnitine Contents in Feedstuffs. In: L-carnitine Folder, Lonza Ltd., Basel.

Bieber, L.L., 1988. Carnitine. Annu. Rev. Biochem. 57: 261-283.

Bisplinghoff, F.D., 1992. Quality standard of animal and plants fats. NO. 222. In: Animal Fats Manual. Fats and Proteins Research Foundation. Inc. Fort. Myers Beach. Florida, pp: 7-8.

Bremer, J., 1983. Carnitine: Metabolism and Functions. Physiol. Rev., 63: 1420-1480.

Buyse, J., G.P.J. Janssens and E. Decuypere, 2001. The effects of dietary L-carnitine supplementation on the performance, organ weights and circulating hormone and Metabolite concentrations of broiler chickens reared under a normal or low temperature schedule. Br. Poult. Sci., 42:230-241.

Cartwright, A.L., 1986. Effect of carnitine and dietary energy concentration on body weight and body lipid of growing broilers. Poult. Sci., 65 (Suppl. 1), 21. (Abstract).

Celik, L., O. Ozturkcan, T.C. Inal, N. Canacankatan and L. Kayrin, 2003. Effects of L-carnitine and niacin supplied by drinking water on fattening performance, carcass quality and plasma L-carnitine concentration of broiler chicks. Arch. Anim. Nutr., 57: 127-136.

Cortinase, L.C., V. Villaverde, J. Galobart, M.D. Baucell, R. Codony and A.C. Barroeta, 2004. Fatty acid content in chickens thigh as affected by dietary polyunsturation level. Poult. Sci., 83: 1155-1164.

Daskiran, M. and R.G. Teeter, 2001. Effects of dietary Lcarnitine (Carniking) supplementation on overall performance and carcass characteristics of seven-week-old broiler chickens. Publ. Oklahoma Agric. Exp. Sta., Oklahoma State Univ., Stillwater, OK., pp: 986.

Deng, K., C.W. Wong and J.V. Nolan, 2006. Long-term effects of early-life dietary L-carnitine on lymphoid organs and immune responses in lrghorn-type chickens. J. Anim. Phys. Anim. Nutr., 90: 81-86.

Feller, A.G. and D. Rudman, 1988. Role of carnitine in human nutrition. J. Nutr., 118: 541-547.

Janssens, G.P.J., J. Mast, B.M. Goddeeris, E. Cox, M. Hesta and R.O.M. De Wilde, 2000. Enhanced specific antibody response to bovine serum albumin in pigeons due to L-carnitine supplementation. Br. Poult. Sci., 41: 448-453.

Leibetseder, J., 1995. Studies of L-carnitine effects in poultry. Arch. Anim. Nutr., 48: 97-108.

Lettner, V.F., W. Zollitsch and E. Halbmaye, 1992. Use of L-carnitine in the broiler ration. Bodenkultur, 43: 161-167.

Lien, T.F. and Y.M. Horng, 2001. The effect of supplementary dietary L-carnitine on the growth performance, serum component, carcass traits and enzyme activities in relation to fatty acid β-oxidation of broiler chicks. Br. Poult. Sci., 42: 92-95.

Mast, J., J. Buyse and B.M. Goddeeris, 2000. Dietary L-carnitine supplementation increases antigen-specific immunoglobulin G production in broiler chickens. Br. J. Nutr., 83: 161-166.

Mateos, G.G. and J.L. Sell, 1981. Influence of fat and carbohydrate source on rate of food passage of semipurified diets for laying hens. Poult. Sci., 60: 2114-2119.

National Research Council, 1994. Nutrient Requirements of Domestic Animals. Nutrient Requirements of Poultry. 9th Rev. Edn., Natl. Acad. Press, Washington, DC.

Owen, K.Q., J.L. Nelssen, R.D. Goodband, M.D. Tokach and K.G. Friesen, 2001. Effect of dietary L-carnitine on growth performance and body composition in nursery and growing-finishing pigs. J. Anim. Sci., 79: 1509-1515.

Rabie, M.H., M. Szilagyi and T. Gippert, 1997a. Effects of dietary L-carnitine supplementation and protein level on performance and degree of meatiness and fatness of broilers. Acta Biol. Hung., 48: 221-229.

Rabie, M.H., M. Szilagyi, T. Gippert, E. Votisky and D. Gerendai, 1997b. Influence of dietary L-carnitine on performance and carcass quality of broiler chickens. Acta Biol. Hung., 48: 241-252.

Rabie, M.H. and M. Szilagyi, 1998. Effects of L-carnitine supplementation of diets differing in energy levels on performance, abdominal fat content and yield and composition of edible meat of broilers. Br. J. Nutr., 80: 391-400.

Rebouche, C.J. and D.J. Paulson, 1986. Carnitine metabolism and functions in humans. Annu. Rev. Nutr., 6: 41-66.

Rebouche, C.J., 1991. Ascorbic acid and carnitine biosynthesis. Am. Clin. Nutr., 54: 1147-1152.

Sarcia, S., M. Corduk and K. Killine, 2005. The effect of dietary L-carnitine supplementation on growth performance, carcass traits and composition of edible meat in Japanese quail. J. Applied Poult. Res., 14: 709-715.

SAS Institute, 1998. SAS/STAT User,s Guide. Release Version 7.00. SAS Institute Inc., Cary. NC.

Sell, J.L., A. Krogdahl and N. Hanyu, 1986. Influence of age on utilization of supplemental fats by young turkeys. Poult. Sci., 65: 546-554.

Steel, R.G.D. and J.H. Torrie, 1980. Principle and procedures of statistics. 2nd Edn., McGroaw-Hill book Co. Inc., New York.

Wiseman, J. and F. Salvador, 1991. Influence of free fatty acid content and degree of saturation on the AME of fats of broilers. Poult. Sci., 70: 573-582.

Xu, Z.R., M.Q. Wang, H.X. Mao, X.A. Zhan and C.H. Hu, 2003. Effects of L-carnitine on growth performance, carcass composition and metabolism of lipids in male broilers. Poult. Sci., 82: 408-413.