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Combined Effects of Dietary Lipid and L-Carnitineon the Growth Performance and Body Composition of Common Carp, *Cyprinus carpio*

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Abstract: Studies on the interaction between dietary L-carnitine supplements and dietary lipid or energy levels are scarce. A 12-week feeding trial was undertaken to examine four L-carnitine levels (0, 300, 600 and 900 mg kg^{-1} diet) and two levels of lipid (50 and 100 g kg^{-1} diet) on the growth performance, feed utilization, carcass and proximate composition of Common carp, *Cyprinus carpio* fingerlings in 2×4 factorial experiment. Additionally, eight isonitrogenous (300 g protein kg^{-1} diet)) and isocaloric (19 MJ gross energy kg^{-1}) diets were formulated. Fingerlings averaging 12.36±0.45 g were randomly distributed into 24 glass aquaria (160 liters) and each aquarium holding 25 fish was then randomly assigned to one of three replicates of the eight diets. At the end of the growth study, the carcass and the proximate analysis were withdrawn. It was found that the dietary L-carnitinesupplementation at all levels (300, 600 and 900 mg kg^{-1}) significantly ($P<0.05$) increased all growth performance parameters (body weight, body length, weight gain and specific growth rate), increased feed intake (FI) and improved feed conversion ratio (FCR) and protein efficiency ratio (PER). Furthermore, Dietary L-carnitine supplementation significantly ($P<0.05$) increased the percentage of dress-out and flesh and decreased the percentage of by-products. The graded levels of L-carnitine significantly ($P<0.05$) increased protein and reduced fat deposition in Common carp fed low or high-fat diets.

Key words: Common carp · L-carnitine · Growth · Feed utilization · Lipid and protein deposition

INTRODUCTION

In recent years, the lipid content of fish feeds has increased significantly. The main reason for supplementing fish diets with L-carnitine is to increase utilization of dietary lipids and carbohydrates, sparing protein from oxidation [1].

L-carnitine (4-N-trimethylammonium-3-hydroxybutyric acid) is a multi-physiological, bioactive and pollution-free additive known to act as a growth enhancer and as a powerful attractant for fish and crustaceans through better feed conversion and/or increased feed intake [5]. L-carnitine is synthesized from the essential amino acids lysine (peptide-bound) and methionine with the assistance of vitamin C and other secondary compounds produced in the body [6]. Moreover, during lipid catabolism, L-carnitine is required for the transfer of medium and long-chain fatty acids from the cytosol into the mitochondria for energy production [1]. Because L-carnitine increases lipid oxidation, it may permit the use of high-fat diets by reducing the lipid accumulation in tissues. Consequently, improvement in growth rates should be observed. Over the last years, evidence has been provided both to support [7] and reject this hypothesis [8, 9]. The improved energy production in mitochondria through â-oxidation of fatty acids may suggest that exogenous administration of L-carnitine could enhance the performance of fish by improving energy utilization efficiency from lipid oxidation [10]. L-carnitine supplementation showed improved growth performances and feed conversion ratios in red sea bream, *Pagrus major* [11]; common carp, *Cyprinus carpio* [12]; hybrid striped bass, *Moronesaxatilis* × *Moronechrysops* [13], Nile tilapia [14]; beluga, *Husohuso* [5, 7]. It has also been found that there is an increased tolerance of ammonia that cannot be directly explained by the effect of

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L-carnitine [15]. It also increases the rate of protein synthesis and enhancing the generation of metabolic energy [16]. This could stimulate some specific cell functions and may influence several biochemical and physiological process, i.e., cell protection against xenobiotics [10]. Also, supplementation of dietary l-carnitine significantly improved survival of Nile tilapia during overwintering [17].

Protein and fat contents of fish diets are the most important dietary energy sources; nevertheless, protein is also the most expensive feed component [18-21]. An increased dietary fat content could induce a protein-sparing action and improve the utilization of dietary protein. Oxidation of fat and fatty acids provides the most cost effective energy yield per unit weight of dietary ingredient and this may be promoted by a dietary supplementation of L-carnitine. To improve utilization of dietary lipids by fish, L-carnitine has shown promise by improving growth and feed efficiency and reducing lipid deposition in some fish species [7, 9, 10].

The objective of this experiment was to investigate the possibility of using dietary graded L-carnitine levels (0, 300, 600 and 900 mg kg^{-1} diet) to induce a protein-sparing action and improve the utilization of dietary protein in common carp fed low or high fat (50 and 100 g kg^{-1} diet) diets.

MATERIALS AND METHODS

Experimental Diets: The experiment was designed according to a factorial design with 4 levels of L-carnitine (0, 300, 600 and 900 mg kg^{-1} diet) and 2 levels of fat (50 and 100 g kg^{-1}) as experimental factors, using each aquarium as an experimental unit. The experiment was conducted at the experimental facilities of the Fish Nutrition Lab, Department of Animal Production, Faculty of Agriculture, Benha University, Egypt. Two basal isonitrogenous diets (300 g protei kg^{-1} diet) and isocaloric (19 MJ gross energy kg^{-1} diet) were formulated to contain 50 or 100 g fat kg^{-1}diet (Table 1). Each diet was divided into 4 portions and L-carnitine (Arab Company for Pharmaceuticals & Medical Plants–MEPACO-Egypt) was supplemented. Therefore, eight treatments were selected to test four L-carnitine levels at two levels of fat and the diets designated as D1 to D8. All dry ingredients of the fish meal, soybean meal, yellow corn and wheat bran were blended for 5 min and thoroughly mixed with corn oil and vitamin and mineral mixture (Table 1). The ingredients were mixed well and made into dry pellets using a laboratory pellet mill (California Pellet Mill, San Francisco, CA, USA). The pellets (1-mm die) were dried for 4 h at 60°C and stored at -20°C until use.

Experimental Fish and Facilities: Common carp, *Cyprinus carpio* fingerlings were obtained from Abbassahatchery, SharkiaGovernorate, Egypt. Fingerlings were transferred in 50-liter plastic bags filled with water and oxygen to fish Lab. Prior to the beginning of the experiment; fish were acclimatized to the experimental conditions and fed commercial diet (300 g protein kg^{-1}) twice daily to apparent satiation by hand for 15 days. After acclimation, fingerlings (12.36±0.45 g) were stocked into twenty-four 160 L glass aquaria. Three replicate aquaria were randomly assigned to each treatment and each aquarium was stocked with 25 fish. The glass aquaria were supplied with de-chlorinated tap water and were continuously supplied with compressed air. About one-third of the water volume in each aquarium was daily replaced by new aerated fresh water after cleaning and removing of the accumulated excreta. A photoperiod of 12 h light, 12h dark (08.00 to 20.00) was used. Fluorescent ceiling lights have supplied the illumination. Fish were fed their respective diets by hand one of eight experimental diets for 84 days. Fish were given the diets at a daily rate 5% of total biomass. The daily ration was divided into two equal amounts and offered two times a day (9:30 and 14.00). All fish in each aquarium were weighed biweekly and the amount of daily allowance feed was adjusted accordingly.

Water temperature, dissolved oxygen, pH and total ammonia were monitored during the study, to maintain water quality at optimal range for common carp. Water temperature was recorded daily at 13.00 h using a mercuric thermometer suspended at 30 cm depth. Dissolved oxygen (DO) was measured daily at 08.00 h using YSI model 56 oxygen meter (YSI Company, Yellow Springs Instrument, Yellow Springs, Ohio, USA) and pH was recorded daily at 09.00 h using a pH meter (Orion pH meter, Abilene, Texas, USA). Total ammonia was measured two times a week according to APHA [22]. During the period of the feeding trial, the water-quality parameters were averaged (±SD): Water temperature was 26.50±0.7°C: dissolved oxygen, 5.5±0.6 mg/L: pH 8.51±0.4 and total ammonia, 0.19±0.11 mg/L. All tested water quality criteria were suitable and within the acceptable limits for rearing the Common carp, *Cyprinus carpio* fingerlings [23].

Table 1: Composition and proximate analysis of the two basal diets

	Low lipid (50 g Kg^{-1} diet)				High lipid (100 g Kg^{-1} diet)			
	L-carnitine (mg kg^{-1})				L-carnitine (mg kg^{-1})			
Diet composition	0	300	600	900	0	300	600	900
Fish meal	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0
Soybean meal	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0
Yellow corn	37.0	37.0	37.0	37.0	27.0	27.0	27.0	27.0
Wheat bran	7.0	7.0	7.0	7.0	12.0	12.0	12.0	12.0
Corn oil	4.0	4.0	4.0	4.0	9.0	9.0	9.0	9.0
[1]Vit.&Min. mix	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Sum	100	100	100	100	100	100	100	100
Proximate analysis (% dry matter basis)								
Dry matter	95.34	95.12	95.40	95.55	95.78	95.08	95.17	95.72
Protein	30.12	30.17	30.22	30.34	29.78	29.81	29.88	29.71
Lipid	5.32	5.29	5.31	5.34	9.71	9.78	9.72	9.80
Ash	6.96	6.90	6.86	6.91	9.96	9.62	9.18	9.17
Crude fiber	9.87	9.83	9.86	9.78	8.55	9.18	9.06	9.02
[2]NFE	47.73	47.81	47.75	47.63	42.00	41.61	42.16	42.30
[3]GE MJ kg^{-1}	19.10	19.11	19.12	19.12	19.55	19.62	19.68	19.69

[1]Vitamin and mineral mixture $kg^{-1}$of the mixturecontains 4800 I.U. Vit A, 2400 IU cholecalciferol (Vit. D), 40 g Vit E, 8 g Vit K, 4.0 g Vit B_{12}, 4.0 g Vit B2, 6 g Vit B6, 4.0 g, Pantothenic acid, 8.0 g Nicotinic acid, 400 mg Folic acid, 20 mg Biotin, 200 gm Choline, 4 g Copper, 0.4 g Iodine, 12 g Iron, 22 g Manganese, 22 g Zinc, 0.04 g Selenium. folic acid, 1.2 mg; niacin, 12 mg; d-calcium pantothenate, 26 mg; pyridoxine. HCl, 6 mg; riboflavin, 7.2 mg; thiamin. HCl, 1.2 mg; sodium chloride (NaCl, 39% Na, 61% Cl), 3077 mg; ferrous sulfate ($FeSO_4.7H_2O$, 20% Fe), 65mg; manganese sulfate ($MnSO_4$, 36% Mn), 89 mg; zinc sulfate ($ZnSO_4.7H_2O$, 40% Zn), 150 mg; copper sulfate ($CuSO_4.5H_2O$, 25% Cu), 28 mg; potassium iodide (KI, 24% K, 76% I),

[2]Nitrogen free extract (NFE) =100-(CP+EE+CF+Ash)

[3]Gross energy calculated using gross calorific values of 0.2363, 0.3952, 0.1715 and 0.1715 MJ/g for protein, fat, crude fiber and NFE, respectively according to Brett [39]

Growth Performanceiindices: Records of all fish body weight and length were individually measured for each aquarium at the initiation and the termination of the feeding trail. Weight gain (WG), specific growth rate (SGR), feed conversion ratio (FCR) and protein efficiency ratio (PER) were calculated using the following equations:

WG (g/fish)=*FBW–IBW*; SGR% = [*lnFBW- ln* IBW]/t×100, where FBW is final body weight (g); IBW is initial body weight (g); ln= natural logarithmic; t=time in days. FCR=*FI /WG*, where FI is feed intake (g); PER=*WG*/*protein intake* (g).

Proximate Analysis of Fish and Experimental Diets: At the experiment termination, five fish were randomly sampled from each aquarium and slaughtered for carcass analysis. All carcass components were measured according to Lovell [24]. Another three fish were also chosen at random and exposed to the proximate analysis of whole fish body according to the methods of AOAC [25]. Fish and diet samples were oven-dried 105ºC for 24 h, ground and stored at -20ºC for subsequent analysis.Dry matter was determined after drying the samples in an oven (105ºC) for 24 h. Ash by incineration at 550ºC for 12 hours. Crude protein was determined by the micro-kjeldahl method, N×6.25 (using Kjeltech auto analyzer, Model 1030, Tecator, Höganäs, Sweden) and crude fat by Soxhlet extraction with diethyl ether (40–60ºC). Crude fiber content of diets was determined using the method of Van Soest *et al.*[26]. The nitrogen-free extract was computed by taking the sum of values for crude protein, crude lipid, crude fiber and ash then subtracting this sum from 100.

Statistical Analysis: Statistical analysis of the obtained data was analyzed according to SAS [27]. Differences between means were tested for significance according to Duncan's multiple rang test as described by Duncan [28].

RESULTS

Initial Body weight (IBW) and initial body length (IBL) values ranged from 12.11-12.51 g for IBW and 8.64-8.80 cm for IBL with insignificant differences among the different fish groups (Table 2). At the experiment termination, final body weight (FBW) ranged between 36.62-47.85 g and final body length (FBL) ranged between 12.8-14.01 cm for the different fish group and the differences in FBW and FBL were significant.

Table 2: Growth performance of common carp fed diets supplemented with increased doses of fat and L-carnitine

			BW		BL			
Diets	Lipid %	L-carnitine	IBW	FBW	IBL	FBL	WG (g/fish)	SGR%
D1	5	0	12.51	36.62 d	8.90	12.80 b	24.11 d	1.28 c
D2	5	300	12.47	44.07 b	8.69	13.62 ab	31.60 b	1.50 ab
D3	5	600	12.54	41.74bc	9.01	13.49 ab	29.20 c	1.43 bc
D4	5	900	12.42	39.43 c	8.69	13.32 ab	27.01 c	1.38 bc
D5	10	0	12.11	39.07 c	8.86	12.75 b	26.96 c	1.39 bc
D6	10	300	12.12	47.85 a	8.72	14.01 a	35.73 a	1.63 a
D7	10	600	12.16	45.25 a	8.75	13.77 a	33.09 d	1.56 c
D8	10	900	12.35	42.85 bc	8.64	13.52 ab	30.50 b	1.48 ab
Standard error			0.78	1.72	0.23	0.30	0.40	0.06
Two-way ANOVA (P value)								
Lipid			>0.05	<0.01	>0.05	>0.05	<0.01	<0.01
L-carnitine			>0.05	<0.01	>0.05	<0.01	<0.01	<0.05
Lipid× L-carnitine			>0.05	<0.01	>0.05	<0.01	<0.05	<0.01

Means followed by different letters in each column are significantly different (P<0.05).

Table 3: Feed intake and feed utilization of common carp fed diets supplemented with graded doses of fat and L-carnitine

Diets	Lipid %	L-carnitine	FI (g/fish)	FCR	PER
D1	5	0	63.17 g	2.62 a	1.27 d
D2	5	300	69.99 c	2.22 b	1.50 a
D3	5	600	65.66 f	2.25 b	1.48 b
D4	5	900	60.23 h	2.23 b	1.49 ab
D5	10	0	66.86 e	2.48 a	1.34 c
D6	10	300	77.53 a	2.17 b	1.53 a
D7	10	600	73.57 b	2.22 b	1.50 ab
D8	10	900	68.20 d	2.24 b	1.49 a
Standard error			0.25	0.05	0.03
Two-way ANOVA (P value)					
Lipid			<0.01	<0.05	<0.05
L-carnitine			<0.01	<0.05	<0.05
Lipid× L-carnitine			<0.01	<0.05	<0.05

Means followed by different letters in each column are significantly different (P<0.05).

Table 4: Carcass analysis of common carp fed diets supplemented with increased levels of fat and L-carnitine

Diets	Lipid %	L-carnitine	Dress out %	Flesh%	By-product%
D1	5	0	64.47 a	41.48 c	56.98 a
D2	5	300	62.99 a	44.96 b	53.47 b
D3	5	600	60.06 b	46.51 a	51.79 c
D4	5	900	60.47 b	47.99 a	51.17 c
D5	10	0	58.97 c	46.78 a	53.63 b
D6	10	300	61.36 b	47.17 a	51.89 c
D7	10	600	60.77 b	46.61 a	51.65 c
D8	10	900	59.20 c	44.08 b	51.83 c
Standard error			0.82	0.41	0.30
Two-way ANOVA (P value)					
Lipid			<0.05	<0.01	<0.01
L-carnitine			<0.05	<0.01	<0.01
Lipid× L-carnitine			<0.05	<0.01	<0.01

Means followed by different letters in each column are significantly different (P<0.05).

Table 5: Proximate analysis of common carp fed diets supplemented with increased levels of fat and L-carnitine

Diets	Lipid %	L-carnitine	Dry matter%	Protein %	Fat %	Ash %
D1	5	0	27.62	60.18 b	29.19 a	9.84
D2	5	300	27.69	64.10 a	25.71 b	9.59
D3	5	600	27.83	64.85 a	25.24 b	9.60
D4	5	900	26.91	63.78 a	25.25 b	9.73
D5	10	0	28.09	61.85 b	29.14 a	9.73
D6	10	300	27.89	63.67 a	26.28 b	9.28
D7	10	600	26.88	63.33 a	25.88 b	9.22
D8	10	900	27.40	63.13 a	25.42 b	9.13
Standard error			0.46	0.66	0.49	0.29
Two-way ANOVA (P value)						
Lipid			>0.05	<0.01	<0.01	>0.05
L-carnitine			>0.05	<0.01	<0.01	>0.05
Lipid × L-carnitine			>0.05	<0.01	<0.01	>0.05

Means followed by different letters in each column are significantly different (P<0.05)

Weight gain (WG) and specific growth rate (SGR) significantly (P<0.05) varied from 24.11 to 35.73 gm/fish and from 1.28 to 1.63% for SGR. Fish fed D1 and D5 showed the lowest growth performance indices (BW, BL, WG and SGR) in comparison to the different L-carnitine supplemented with the low fat (50 g kg^{-1} diet) diets (D2, D3 and D4) or to the high fat (100 g kg^{-1}) diets (D6, D7 and D8) and fish group fed D6 showed the best growth performance parameters.

Averages of feed intake (FI), feed conversion ratio (FCR) and protein efficiency ratio (PER) ranged between 63.17-77.53 gm/fish, 2.17-2.62 and 1.27-1.53%, respectively. L-carnitine supplementation to the low-fat diets (50 g kg^{-1} diet) or to the high fat diets (100 g kg^{-1} diet) improved FCR and PER. Statistical differences (P<0.05) were found in terms of FCR and PER and paralleled to that obtained for growth performance (BW, BL, WG and SGR).

Results of Table 4 indicated that the high fat diets and 0 L-carnitine D5 recorded the lowest dress-out and flesh and the highest by-products percentages. Proximate composition of common carp (Table 5) showed that theprotein content of the whole body ranged between 60.18-64.85% and fat ranged between 25.24-29.19% and the differences among protein and fat content were significant (P<0.05). The low fat (50 g kg^{-1}) diets (D2, D3 and D4) and the high fat (100 g kg^{-1}) diets (D6, D7 and D8) supplemented with the dietary g raded levels of L-carnitine significantly (P<0.05) increased protein and reduced fat content of common carp bodies. Dry matter and ash content of common carp in the present study had no clear trend and did not significantly affected by the graded levels of L-carnitine.

DISCUSSION

Biological Performance of Fish: Several studies reported that L-carnitine could induce an improved growth performance and protein sparing, probably caused by increased lipid oxidation in several marine and freshwater species [5, 7, 10, 11, 14, 29-32]. In contrast, dietary carnitine did not affect growth of channel catfish [33], rainbow trout [8], Atlantic salmon [9], African catfish [34], European seabass, *Dicentrarchus labrax*[35], or tilapia [36]. This variation in the effect of L-carnitine in different fish species as recorded by several authors is not attributed to the concentration of dietary L-carnitine, because low carnitine concentrations (350 mg kg^{-1}) caused an increase in the weight gain (WG), feed efficiency (FE), protein efficiency ratio (PER) and condition factor (CF) of beluga, *Husohuso*[7], while high concentrations (from 1000 to 3000 mg kg^{-1} diet) had no significant effect on growth of channel catfish [33], rainbow trout [8], Atlantic salmon [9], African catfish [34], European seabass, *Dicentrarchus labrax* [35]or tilapia [36]. Moreover, Ma *et al.*[31]observed that L-carnitine in the level of 100-240 mg kg^{-1} diet caused a better growth rate in juvenile black sea bream (*Sparus macrocephalus*), while L-carnitine at further increment (390 or 1100 mg kg^{-1} diet) reduced growth performance. These contradicting results suggest that growth-enhancing effects of dietary L-carnitine supplements had been influenced by other factors in addition to diet composition, such as species differences, developmental stage and husbandry conditions. As noted by Becker *et al.* [29] a positive effects of dietary L-carnitinesupplements have been

found, a linear dose/response relationship can be established, whereas in this study and other studies the dose/response relationship seems non-linear, with one very efficient dose combined with neutral or even negative responses as the dietary L-carnitine level increased.

One of the most common explanations for the growth improvement effect of L-carnitine feeding is a more efficient utilization of energy from fatty acids. Ji *et al.* [9] provided evidence on the mechanism by which dietary L-carnitine may alter some indices of intermediary metabolism by stimulating fatty acid oxidation in Atlantic salmon. Their results suggested induction of pyruvate carboxylase (or a reduction of turnover) and enhanced protein synthesis as the mechanism for carnitine-induced changes in gluconeogenesis and nitrogen metabolism.

Feed intake and feed utilization in this study show a significant improvement in all fish groups fed L-carnitine. The simultaneous improvement of FI, FCR and PER in fish fed L-carnitine supplemented diets will be reflected on enhanced biomass gain. Similarly, several researchers have speculated that, increased growth rates of fish fed supplemental carnitine were due to improved feed conversion via increased fatty acid oxidation and increased utilization of dietary energy as observed by Azab *et al.* [14] in tilapia, Becker and Focken [37] in common carp and Mohseni and Ozorio [7] in beluga, *Husohuso*). In contrast, other researchers observed a significant increase in feed consumption and growth rates without significant improvement in feed efficiency [13] in hybrid striped bass.

Our results indicated that, for the two dietary lipid levels (50 or 100 g kg^{-1}) the diets contained the lower L-carnitine level (300 mg kg^{-1}diet) released the best growth and feed utilization indices (BW, BL, WG, SGR, FCR and PER) which did not significantly different from the higher L-carnitine levels (600 and 900 mg kg^{-1}diet) and this indicated that dietary L-carnitine at the lower level (300 mg kg^{-1}) is effective in improving growth and feed utilization of common carp. The optimum level of L-carnitine supplementation found in this study (300 mg kg^{-1}) is similar to that found by Focken *et al.* [12] for Common carp, *Cyprinus carpio* (400 mg kg^{-1}) and Mohseni and Ozorio [7] for beluga, *Husohuso.*

The best growth performance and feed utilization were detected in the fish group fed D6 that contained the high-fat level (100 g kg^{-1}) and supplemented with the low L-carnitine dose (300 mg kg^{-1} diet). The improved utilization of lipids as sources of energy induced by dietary L-carnitine supplements might explain the beneficial effects observed. These results suggest a protein-sparing action of L-carnitine, perhaps through enhanced β-oxidation of dietary fat.

The lack of a strong L-carnitine effect on common carp at the higher levels (600 and 900 mg kg^{-1} diet) in this study appears to be due to the ability of fish synthesize adequate quantities of L-carnitine for lipid metabolism. The diets were limiting in lysine or methionine which are precursors for L-carnitine synthesis. If a limited precursor pool was available for metabolism, the higher L-carnitine levels may have more dramatic influences on growth and/or proximate composition of gain. In African catfish, Torreele *et al.* [38] showed that dietary L-carnitine supplements improved the overall growth performance, but the effectiveness of L-carnitine feeding was higher in fish fed a low-fat diet (9.6%) than in those fed a diet containing a higher lipid level (15.5%). By contrast, Chatzifotis *et al.* [4] and Azab *et al.* [14] failed to establish any relationship between dietary L-carnitine supplementation and incremental dietary lipid levels (10 and 15%) in terms of growth rate and feed efficiency in rainbow trout and Nile tilapia, respectively.

Carcass and Proximate Analysis of Common Carp: Dietary L-carnitine supplementation significantly increased the percentages of flesh and decreased by-products (Table 4). Proximate compositions showed that the low or the high fat levels (50 or 100 g kg^{-1} diet) with the graded levels of dietary L-carnitine supplementation produced a substantial reduction in the body energy storage. L-Carnitine plays an important role in promoting the transport of long-chain fatty acids across the inner mitochondrial membrane, resulting in extra energy from â-oxidation. Therefore, dietary L-carnitine supplements should enhance the oxidation of these fatty acids, thereby decreasing their availability or esterification to triacylglycerols and deposition in the various lipid storage tissues [35]. The ability of L-carnitine to increase protein and reduce tissue lipid content has been evaluated in several fish species with conflicting results. Fat content of several tissues, such as liver, muscle and viscera, were reduced as the L-carnitine supplemented to the diets of channel catfish [33], tilapia [30], Atlantic salmon [9], juvenile black sea bream [31] and beluga, *Husohuso* [5, 7]. In contrast, the absence of a lipotropic action of carnitine feeding had been previously reported in red seabream, rainbow trout, hybrid tilapia, hybrid striped bass, European seabass, *Dicentrarchus labrax* and Nile tilapia [4, 8, 10, 11, 13, 14, 29, 35]. Whether such variability in terms of the body lipid lowering effect of supplemental

L-carnitine is associated with dietary lipid level (and indirectly to the energy density of the diet) remains unclear. Whereas Rodehutscord [8] reported that supplemental dietary L-carnitine was ineffective for reducing body fat in rainbow trout fed high-fat diets (26%), Ji *et al.* [9], in Atlantic salmon fed a 10% lipid diet, found that carnitine-fed fish exhibited a decrease in the lipid content in white muscle and viscera by as much as 73 and 43%, respectively. However, we should not forget that such changes in dietary lipid levels imply changes in the fatty acid composition of diets, a factor of great importance because L-carnitine is mainly associated with the oxidation of long-chain fatty acids. Apart from the dietary lipid level and given its important role in carnitine biosynthesis, dietary lysine has also been found to affect lipid.

From the obtained results we suggest that the increased tissue protein and decreased fat during dietary L-carnitine supplementation was a result of decreased amino acid oxidation and a possible increase in fatty acid combustion for energy. Common carp fingerlings fed dietary L-carnitine-supplemented diets showed an improvement in either growth rate and feed conversion efficiency. Therefore, the use of L-carnitine supplements in aquaculture can enable fish farmers to effectively use high-fat diets by reducing the lipid accumulation and protein breakdown in tissues, thereby improving the farm economy and decreasing emission of nitrogen waste to the environment. Further investigation on the effect of dietary L-carnitine on the nutrient dynamics is still necessary.

CONCLUSION

In conclusion, supplemental dietary L-carnitine does (300 mg kg^{-1} diets) have beneficial effects on improving growth performance and protein retention, possibly as a result of increasing protein-sparing effects of lipids. Also, supplementation of L-carnitine reduced whole-body lipid deposition and increased tissue protein content in common carp, *Cyprinus carpio*taking in consideration the economic cost of L-carnitine supplementation to fish diet

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