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# The effect of dietary L-carnitine and fat on performance, carcass traits and blood components in broiler chickens\*

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The poultry industry has traditionally been selecting animals for improved performance without consideration for the effect on fat deposition. Dietary L-carnitine can alter lipid metabolism; nevertheless, when combined with fat, the effects are not clear. This study shows the effect of different dietary levels of L-carnitine (0, 200 and 400 mg/kg) and fat (0, 2.5 and 5%) on growth performance and slaughter traits of commercial broilers (Ross 308; n=270). The groups received the following dietary treatments: 1) 0 mg/kg L-carnitine + 0% fat, 2) 200 mg/kg L-carnitine + 0% fat, 3) 400 mg/kg L-carnitine + 0% fat, 4) 0 mg/kg L-carnitine + 2.5% fat, 5) 200 mg/kg L-carnitine + 2.5% fat, 6) 400 mg/kg L-carnitine + 5.0% fat, 7) 0 mg/kg L-carnitine + 5.0% fat, 8) 200 mg/kg L-carnitine + 5.0% fat, explore the solution of the second biochemical parameters, carcass traits and body composition were measured and analyzed. Levels

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of fat with L-carnitine had significant effects on the European Performance Efficiency Factor, wings weight, intestine length and weight, spleen and liver weight, full abdomen carcass and abdominal fat weight, as well as serum triglyceride levels. Dietary L-carnitine supplementation improved growth performance of broilers, thus it may be a promising solution to reduce fat storage in broilers and improve the quality of carcasses intended for human consumption.

#### KEY WORDS: blood lipids / carcass traits / fat / L-carnitine / performance / poultry

Over the last 50 years different studies have been conducted to determine the influence of diet supplementation on carcass composition and more recently, also on blood parameters [Pearson and Dutson 2013]. The poultry industry has traditionally been selecting animals for improved performance (high growth rate, body weight, feed efficiency) without considering the effect on fat deposition. The intramuscular lipid accumulation affects mainly the abdominal adipose tissue, considered by the broiler industry a product of low economic value, which resulted in a re-evaluation of the improvement strategies incorporating new dietary technologies [Fouad et al. 2013]. L-carnitine (3-hydroxy-4-N-trimethylammoniobutanoate) is endogenously biosynthesized from lysine and methionine [Buyse et al. 2001]. Although its relative concentration in cells (in the form of free carnitine or acylcarnitines) is high, an exogenous dietary intake is needed. L-carnitine in the form of acylcarnitines facilitates the transport of fatty acids into the mitochondrial matrix [Furuno et al. 2001]. The concept that dietary L-carnitine reduces cholesterol and triglyceride levels has been supported by the study of Wang et al. [2013], demonstrating the moderating influence of altering lipid metabolism on body fat. The dietary fat and L-carnitine combination effects on lipid metabolism and growth development of broiler chickens are not clear. Therefore, the objective of this study was to investigate the effects of dietary L-carnitine and fat on the performance, carcass characteristics and blood parameters in broiler chicks.

## Material and methods

#### Animals

A total of 270 one-day old mixed Ross 308 chicks (weighing  $44.0\pm1.5$  g) were divided into 27 groups of 10 animals each. All birds were fed iso-caloric and iso-nitrogenous diets for 42 days (see the composition and nutritive values in Tab. 1). Furthermore, different L-carnitine (0, 200 and 400 mg/kg) and fat (corn oil 0, 2.5 and 5%) concentrations were added to the daily diet. The treatment groups (each treatment had three replicated pens) were as follows:

Treatment 1 (control) -0% fat +0 mg/kg L-carnitine, Treatment 2-0% fat +200 mg/kg L-carnitine, Treatment 3-0% fat +400 mg/kg L-carnitine, Treatment 4-2.5% fat +0 mg/kg L-carnitine, Treatment 5-2.5% fat +200 mg/kg L-carnitine, Treatment 6-2.5% fat +400 mg/kg L-carnitine, Treatment 7-5% fat +0 mg/kg L-carnitine, Treatment 8-5% fat +200 mg/kg L-carnitine, Treatment 9-5% fat +400 mg/kg L-carnitine, Treatment 9-5% fat +400 mg/kg L-carnitine, Treatment 1200 mg/kg L-carnitine, Treatment 1200

	Starter	Finisher	Finisher
Ingredient (g/kg)	period	period	period
Feed ingredients			
corn	558.5	624	630
soybean meal	375.5	320.5	302.5
soybean oil	20	20	20
monocalcium phosphate (CaH <sub>4</sub> P <sub>2</sub> O <sub>8</sub> )	17	11	13
CaCO <sub>3</sub>	11.3	13	9
Mineral mixture <sup>1</sup>	3	2.5	3
Vitamin mixture <sup>2</sup>	3	2.5	3
Vitamin K3	1	1	1
Vitamin E	1	1	0.5
DL-Methionine	3.3	1.8	1.7
Lysine-hydro-chloride	2.2	1	1
NaCl	1.9	2	2.5
sodium bicarbonate (NaHCO <sub>3</sub> )	2.5	1.5	1.5
multi-enzyme	0.35	0.35	0.35
phytase	0.1	0.1	0.1
total	100	100	100
Nutrient analysis			
metabolizable energy (kcal/kg)	2930	3050	3100
crude protein (%)	23	21.5	20
crude fiber (%)	3	3	2.90
calcium (%)	1	0.86	0.80
available phosphorus (%)	0.5	0.43	0.40
sodium (%)	0.16	0.16	0.16
lysine (%)	1.28	1.1	1.00
methionine (%)	0.58	0.45	0.45
Ca:P	2	2	2.00
linoleic acid (%)	1	1	1.00
potassium (%)	0.8	0.8	0.8
methionine + cysteine (%)	0.93	0.77	0.75
chlorine (%)	0.16	0.15	0.15

Table 1. Feed ingredients and nutrient analysis of diets used during the starter(1<sup>st</sup>-14<sup>th</sup> days of age), grower (15<sup>th</sup>-28<sup>th</sup> days of age) and finisherperiods (29<sup>th</sup>-42<sup>nd</sup> days of age)

 $^1Calcium pantothenate - 4 mg/g; niacin - 15 mg/g; Vitamin B6 - 13 mg/g; Cu - 3 mg/g; Zn - 15 mg/g; Mn - 20 mg/g; Fe - 10 mg/g; K - 0.3 mg/g.$ 

 $^2$ Vitamin A – 5000 IU/g; Vitamin D3 – 500 IU/g; Vitamin E – 3 mg/g; Vitamin K3 – 1.5 mg/g; Vitamin B2 – 1 mg/g.

#### Management of experimental birds

On the first day of age all birds were weighed individually and then randomly assigned to 27 floor pens. During the first three weeks of rearing the room temperature was set at 33°C in the first days, dropped to 30°C in the successive days of the first week, and subsequently lowered gradually by 2.8°C every week until 20°C was reached. Room temperature was monitored by three thermometers placed in the middle and two ends of the broiler house. The birds were kept under a 23-hour light regimen throughout the study period. Feed and water were provided *ad libitum*, during

the first week in feeder trays and conical drinkers, respectively. During the rest of the rearing period, cylindrical feeders and drinkers were used. The birds were vaccinated on the 1<sup>st</sup> day of age against infectious bronchitis and avian influenza, on the 1<sup>st</sup>, 8<sup>th</sup> and 18<sup>th</sup> day of age against Newcastle disease and on the 14<sup>th</sup> and 22<sup>nd</sup> days of age against Gumboro's disease. Body weight and feed intake were measured weekly. Feed conversion ratio (FCR) was calculated by dividing total feed consumption by total body weight gain (g/g bwg) and the European production efficiency factor (EPEF) was calculated weekly using the following equation: EPEF = Daily weight gain (g or kg) × Survival rate/10 × FCR.

On day 42 one representative chick per group was sacrificed. The carcass was then processed into edible parts and non-edible parts. Feet were separated from the carcass at the tibiotarsal joint. The neck, wingtips, gut and liver were removed and the empty or edible carcass was weighed.

### Blood collection and analysis

On day 42 one bird with a weight close to the mean was selected, a 5ml blood sample was taken from the wing vein and held for 12 hours at room temperature, centrifuged at 5,000 rpm for 3 minutes (before serum separation). Serum was stored at -20°C until biochemical analysis. Analysis was performed using Pars Azmoon commercial kits in an autoanalyzer (Hitachi 917, Japan). The levels of direct and total bilirubin, alkaline phosphatase, aspartate amino transferase (S.G.O.T) (EC 2.6.1.1), creatinine, blood urea nitrogen, low-density lipoprotein, high-density lipoprotein, triglycerides, total cholesterol and glucose were measured.

#### Statistical analysis

The data were analyzed using a general linear model (SAS Institute Inc. 2000., SAS Online Doc., SAS Institute Inc., Cary, NC.), which is robust enough to allow for the moderately imbalanced data from these experiments. The model included L-carnitine and fat as the main effects. A  $3\times3$  factorial design was used to analyze the data. The interaction between the main effects was included in the model. Group differences were tested with Duncan's test. The significance level was set at P<0.05. The model used was:

$$y_{ij} = \mu + A_i + B_j + (AB)_{ij} + e_{ijk}$$

where:

 $\mu$  – the overall mean;

 $A_i$  – the fixed effect of L-carnitine;

 $B_i$  – the fixed effect of fat;

 $(AB)_{ii}$  - the fixed effect of interaction A by B;

 $e_{iik}$  – the random error.

Before the statistical analysis of data, all data were tested by Shapiro-Wilk's and Levene's tests for normality and homogeneity of variance, respectively.

# **Results and discussion**

#### Main effects

The effects of dietary fat on the growth performance of six-week old broilers are summarized in Table 2. The dietary supplementation of 5% fat decreased the feed conversion ratio (FCR, P<0.05) and increased the European Production Efficiency Factor (EPEF, P<0.05), while it had no effect on body weight (BW) when compared to the controls. Of all the analyzed carcass components (Tab. 4), the weight of abdominal fat was greater in broilers fed 5% supplemental fat compared to the controls, similarly as it was for full abdomen carcass weight (P<0.05) compared to birds fed the low-fat diet (2.5% fat). Weight of other carcass components as well as the spleen (Tab. 3) was not influenced markedly by the fat supplementation diets. The effect of fat rich diets on gastrointestinal components and organs is shown in Table 5. Fat rich diets (2.5% and 5%) increased the intestine weight (P<0.05) compared to the control birds. The low-fat diet increased the intestine weight, while it decreased liver weight (both P<0.05, Tab. 5). Other parameters as well as blood biochemistry parameters (Tab. 6) were not significantly affected by fat rich diets. High fat diets used in broiler nutrition to improve their BW lead to increased carcass fat deposition. In this study the highfat diet (5% fat) had no effect on BW even though it improved FCR, which is in line with the study of Rezaei et al. [2007] in broiler chicks fed 5% supplemental fat. In turn, Burlikowska et al. [2010] found no effect of the diet fortified with lard on the BW gain and FCR.

The EPEF is used to evaluate growth performance of broilers [Kryeziu *et al.* 2018]. In the present study, only feeding the high-fat diet resulted in increased EPEF, which indicated a uniform BW gain as well as good health of birds [Bhamare *et al.* 2016]. The intestine, full abdomen carcass and abdominal fat weights were found to increase after feeding the 5% supplemental fat. The deposition of body fat depends on the net balance between fat absorption, synthesis and catabolism [Mohammad and Horniaková 2012]. In another study, dietary fat did not alter blood parameters in broilers fed with lard [Burlikowska *et al.* 2010].

Of the investigated carcass components (Tab. 4), only the neck and abdominal fat weights (both P<0.05) were decreased in broilers fed a diet supplemented with L-carnitine compared to the controls. Growth performance (Tab. 2), spleen weight (Tab. 3), gastrointestinal component and organ weights (Table 5) and blood serum biochemical indices (Tab. 6) were not altered markedly. Endogenous L-carnitine supports energy metabolism by mobilizing fat from body reserves [Rabie *et al.* 1997]. Supplemental L-carnitine (200 and 400 mg/kg) decreased the weight of the neck and abdominal fat, while no other carcass or blood parameters and growth performance of broilers were affected markedly. Our observations are in agreement with those of Wang *et al.* [2013], who found no effect of dietary L-carnitine on broiler performance, growth rate or feed efficiency, except for triglyceride mobilization properties. In contrast, Rabie and Szilágyi [1998] found a clear positive effect of L-carnitine on

Main effects		Fat (%)			Ľ	-carnitine (mg/kg	()		
	0	2.5	5		0	200	400		
FCR (g/g bwg)	$1.83^{a}(0.04)$	$1.78^{ab}(0.10)$	$1.73^{b}(0.07)$		$1.77^{a}(0.08)$	$1.78^{a}(0.10)$	$1.79^{a}0.08$		
Body weight (kg)	$2.36^{a}(0.07)$	$2.41^{a}(0.13)$	$2.46^{a}(0.09)$		$2.44^{a}(0.08)$	$2.42^{a}(0.11)$	$2.37^{a}(0.12)$		
EPEF	308.00 <sup>b</sup> (13.47)	324.51 <sup>ab</sup> (42.35)	339.99 <sup>a</sup> (17.77)		$330.32^{a}(22.87)$	$325.93^{a}(32.18)$	$315.64^{a}(30.15)$		
Interaction effects	T1	T2	T3	T4	T5	T6	T7	T8	T9
FCR (g/g bwg)	$1.83^{a}(0.05)$	$1.80^{a}(0.03)$	$1.86^{a}(0.00)$	$1.73^{a}(0.05)$	$1.83^{a}(0.14)$	$1.76^{a}(0.12)$	$1.74^{a}(0.10)$	$1.70^{a}(0.07)$	$1.74^{a}(0.07)$
body weight (kg)	$2.42^{a}(0.07)$	$2.37^{a}(0.02)$	$2.28^{a}(0.04)$	$2.47^{a}(0.06)$	$2.41^{a}(0.19)$	$2.36^{a}(0.14)$	$2.43^{a}(0.12)$	$2.49^{a}(0.07)$	$2.46^{a}(0.09)$
EPEF	$318.40^{ab}(13.47)$	) 313.16 <sup>ab</sup> (8.69)	292.42 <sup>b</sup> (6.54)	339.85 <sup>ab</sup> (15.73)	315.94 <sup>ab</sup> (46.65)	317.74 <sup>ab</sup> (42.35)	332.70 <sup>ab</sup> (36.14)	$348.69^{a}(26.83)$	336.76 <sup>ab</sup> (17.77)

Table 2. Growth performance means and standard errors (in parentheses) of Ross 308 male broilers fed different levels of dietary fat and L-carnitine in the first six weeks of

⊔at ung/Kg L--0% fat + 200 mg/kg L-carnitue; 13 -0% fat + 400 mg/kg L-carnitue; 14 -2.5% fat + 0 mg/kg L-carnitue; 15 -2.5% fat + 20 mg/kg L-carnitine; T7 -5% fat + 0 mg/kg L-carnitine; T9 -5% fat + 400 mg/kg L-carnitine. Means with different superscripts within each row of dictary treatments differ significantly at P<0.05.

Main effects		Fat (%)			Ľ	-carnitine (mg/k	g)		
Organ weight (g)	0	2.5	5		0	200	400		
Spleen	$2.22^{a}(0.57)$	$2.55^{a}(1.00)$	$2.22^{a}(0.57)$		$2.55^{a}(0.52)$	$1.89^{a}(0.60)$	$2.55^{a}(0.72)$		
Interaction effects	T1	T2	T3	T4	T5	T6	T7	T8	T9
Spleen	$2.33^{ab}(0.57)$	$2.00^{ab}(0.00)$	$2.33^{ab}(0.57)$	$2.66^{ab}(0.57)$	$2.00^{ab}(1.00)$	$3.00^{a}(1.00)$	$2.66^{ab}(0.57)$	$1.66^{b}(0.57)$	$2.33^{ab}(0.57)$

Table 3. Immune organ means and standard errors (in parentheses) of Ross 308 male broilers fied different levels of dictary fat and L-carnitine in the first six weeks of age

T1 (control) – 0% fat + 0 mg/kg L-carnitine; T2 – 0% fat + 200 mg/kg L-carnitine; T3 – 0% fat + 400 mg/kg L-carnitine; T4 – 2.5% fat + 0 mg/kg L-carnitine; T5 – 2.5% fat + 400 mg/kg L-carnitine; T6 – 2.5% fat + 400 mg/kg L-carnitine; T6 – 2.5% fat + 400 mg/kg L-carnitine; T6 – 2.5% fat + 400 mg/kg L-carnitine; T7 – 5% fat + 0 mg/kg L-carnitine; T8 – 5% fat + 400 mg/kg L-carnitine; T9 – 5% fat + 400 mg/kg L-carnitine; T6 – 2.5% fat + 400 mg/kg L-carnitine; T7 – 5% fat + 0 mg/kg L-carnitine; T8 – 5% fat + 400 mg/kg L-carnitine; T9 – 5% fat + 400 mg/kg L-carnitin carnitine.

<sup>ab</sup>Means with different superscripts within each row of dietary treatments differ significantly at P<0.05.

$\begin{array}{c c} \hline \hline 0 $	2.5 53.88°(4.35) 53.88°(4.35) 124.56°(9.81) 1.78°(0.53) 698.33°(38,00) 45.55°(14.16) 45.55°(14.16) 120.66°(16.77) 2.09°(152.33) 34.66°(4.16) me; T2 - 0% fat + wgkg L-carnitine; n each row of dict	$\begin{array}{c} 5\\ 659, 44^{*}(62,95)\\ 55, 88^{*}(3,60)\\ 25, 88^{*}(3,60)\\ 2.17^{*}(0,29)\\ 705, 44^{*}(3,60)\\ 51, 55^{*}(12,08)\\ 51, 55^{*}(12,08)\\ 51, 55^{*}(12,08)\\ 116, 00^{*}(2,64)\\ 1.82^{*0}(0,12)\\ 16, 35^{*}(1,52)\\ 16, 35^{*}(1,52)\\ 16, 35^{*}(1,52)\\ 16, 35^{*}(1,52)\\ 16, 35^{*}(1,52)\\ 16, 35^{*}(1,52)\\ 16, 35^{*}(1,52)\\ 16, 35^{*}(1,52)\\ 17, -5^{*6} \text{ fat} + 0 \text{ n}\\ \text{ary treatments diff}\\ tandard errors (in tandard errors (i$	T4 59.66°(48.18) 59.66°(6.65) 124.00°(3.60) 1.63 <sup>b</sup> (0.41) 1.63 <sup>b</sup> (0.41) 1.63 <sup>b</sup> (0.41) 1.63 <sup>b</sup> (0.41) 1.63 <sup>b</sup> (1.41) 1.63 <sup>b</sup> (1.41) 1.6	$\begin{array}{c} 0 \\ 668.33^{4}(6.92) \\ 58.66'(22) \\ 58.66'(2.29) \\ 127.00'(13.87) \\ 1.90'(0.35) \\ 704.44'(2.13) \\ 51.55^{4}(9.24) \\ 51.55^{4}(9.24) \\ 51.00'(11.26) \\ 1.74^{4b}(0.22) \\ 640.66'(129.24) \\ 640.66'(129.24) \\ 51.66^{4}(2.22,67) \\ 1.74^{4b}(0.22) \\ 1.74^{4b}(0.22$	200 622.117(74.39) 52.22 <sup>b</sup> (6.61) 1.928 <sup>a</sup> (0.43) 656.117(106.36) 44.66 <sup>ab</sup> (14.16) 709.33 <sup>a</sup> (57.93) 1.74 <sup>ab</sup> (0.35) 1.74 <sup>ab</sup> (0.35) 1.74 <sup>ab</sup> (0.53) 35.66 <sup>ab</sup> (2.88) 35.66 <sup>ab</sup> (2.86) 35.66 <sup>ab</sup> (2.86) 35.66 <sup>ab</sup> (2.86) 35.66 <sup>ab</sup> (2.80) 35.66 <sup>ab</sup> (2.80) 35.6 <sup>ab</sup> (2.80) 35	400 51.88%(5.21) 51.88%(3.85) 21.8%(3.85) 2.01*(0.46) 730.22*(4.681) 34.00*(16.95) 770.23*(38.83) 59.33*(3.5.1) 125.33*(1.52) 2.09*(14.00) 57.00*(14.00) 57.00*(14.00) 57.00*(14.00) 125.33*(1.52) 2.09*(14.00) 125.33*(1.52) 125.33*(1.52) 2.09*(14.00) 125.33*(1.52) 125.33*(1.52) 2.00*(14.00) 57.00*(14.00) 125.33*(1.52) 125.33*(1.52) 125.33*(1.52) 125.33*(1.52) 125.33*(1.52) 125.33*(1.52) 125.33*(1.52) 125.33*(1.52) 125.33*(1.52) 125.33*(1.52) 125.33*(1.52) 125.33*(1.52) 125.33*(1.52) 125.33*(1.52) 125.33*(1.52) 126.33*(1.52) 126.33*(1.52) 126.33*(1.52) 126.33*(1.52) 127.34*(1	T8 (629,00°(103,01) 56.33 <sup>ab</sup> (15,88) 1.95 <sup>ab</sup> (0.37) 66.2.66 <sup>ab</sup> (5.83) 42.66 <sup>ab</sup> (5.85) t+400 mg/kg L-carnitic	T9         F9           681.00%(62.95)         52.0%(3.60)           134.33%(17.38)         2.47%(0.29)           753.33%(3.05)         50.00%(16.82)           50.00%(16.82)         50.00%(16.82)           atmitine.         - 2.5% fat + 200
$\begin{array}{c c} Drumsticks & 633.11^{*}(109.57 \\ Neck & 53.00^{*}(2.65) \\ Full abdomen carcass & 1.26^{*0}(0.165) \\ Breast & 687.00^{*}(57.51) \\ Abdominal fat & 33.11^{*}(14.27) \\ Interaction Effects & 687.00^{*}(57.51) \\ Drumsticks & 57.00^{*}(7.00) \\ Neck & 57.00^{*}(109.57 \\ Ning & 131.66^{*0}(0.19) \\ Ning & 131.66^{*0}(0.10) \\ Neck & 704.33^{*0}(4.72) \\ Abdominal fat & 48.33^{*0}(4.72) \\ Abdominal fat & 48.33^{*0}(4.72) \\ IT (control) - 0\% fat + 0 mg/kg L-carmitine; T6 - 2.5\% fat + 400 \\ mg/kg L-carmitine; T6 - 2.5\% fat + 400 \\ mg/kg L-carmitine; T6 - 2.5\% fat + 400 \\ mg/kg L-carmitine; T6 - 2.5\% fat + 400 \\ \end{array}$	<ul> <li>660.44°(57.93)</li> <li>757.93)</li> <li>72.88°(4.35)</li> <li>17.8°(0.55)</li> <li>698.33°(38.00)</li> <li>45.55°(14.16)</li> <li>72</li> <li>660.00°(50.26)</li> <li>49.33°(4.16)</li> <li>120.66°(16.77)</li> <li>20.96°(16.77)</li> <li>34.66°c(4.16)</li> <li>ne; T2 - 0% fat + ugkg L-carnitine;</li> <li>ne cach row of dict</li> <li>ngan means and s</li> </ul>	$\begin{array}{c} 659.44^{a}(62.95)\\ 25.88(3.60)\\ 25.88(3.60)\\ 2.17^{0}(0.7.38)\\ 2.17^{0}(2.29)\\ 705.44^{a}(3.60)\\ 51.55^{a}(12.08)\\ 1.5.5^{a}(12.08)\\ 1.5.56^{a}(5.03)\\ 116.00^{ab}(2.64)\\ 1.82^{ab}(0.12)\\ 691.66^{a}(62.64)\\ 1.82^{ab}(1.22)\\ 691.66^{a}(62.64)\\ 1.6.00^{ab}gL-earr\\ 1.72-5\% \ fat+0\ n\\ ary\ treatments\ dil$	T4 694.66 <sup>a</sup> (48.18) 59.66 <sup>a</sup> (6.65) 124.00 <sup>b</sup> (5.60) 1.63 <sup>b</sup> (0.41) 708.66 <sup>a</sup> (93.55) 49.33 <sup>ab</sup> (7.50) anitine; T3 – 0% f mitine; T3 – 0% f nitine; T3 – 0% f parentheses) of l	668.33*(66.92) 28.66*(5.29) 19.00*(13.87) 19.00*(13.87) 19.00*(13.87) 51.55*(9.24) T5 577.33*(61.37) 51.00*(8.71) 109.00*(11.26) 1.74**(0.22) 64.06*(129.24) 51.66*(129.24) 51.66*(129.24) 51.66*(129.24) 51.66*(129.24) 51.66*(129.24) 51.66*(129.24) 51.66*(129.24) 51.66*(129.24) 51.66*(129.24) 51.66*(129.24) 51.66*(129.24) 51.66*(129.24) 51.66*(129.24) 51.66*(129.24) 51.66*(129.24) 51.65*(120.22) 51.65*(120.25) 51.65	622.11*(74.39) 52.22°(6.61) 118.00*(14.61) 1.920*(14.36) 44.66 <sup>th</sup> (14.16) 709.33*(57.93) 55.00°(4.35) 1.746 <sup>48</sup> (0.81) 1.746 <sup>48</sup> (0.81) 1.746 <sup>48</sup> (0.83) 35.66 <sup>th</sup> (2.88) 35.66 <sup>th</sup> (2.88) 35.66 <sup>th</sup> (2.88)	622.56 <sup>6</sup> (76.21) 51.88(3.85) 2.01 <sup>30</sup> (14.98) 2.01 <sup>30</sup> (14.98) 730.22 <sup>a</sup> (46.81) 34.00 <sup>b</sup> (16.95) 59.33 <sup>4</sup> (3.51) 125.33 <sup>4</sup> (1.52) 2.09 <sup>b</sup> (1.52) 2.09 <sup>b</sup> (1.400) 57.00 <sup>b</sup> (1.400) 57.00 <sup>b</sup> (1.400) 57.00 <sup>b</sup> (1.400)	T8 (29,00°(103,01) 56,33°(6,42) 1,95°(0,37) 1,95°(0,37) 66,26°(6,36) 42,66°(5,85) 1,95°(6,06) 42,66°(5,85) 1,95°(6,06) 42,66°(5,85) 1,95°(6,06) 42,66°(5,85) 1,15°(5,85) 42,66°(5,85)42,66°(5,85) 42,66	T9 681.00 <sup>9</sup> (62.95) 52.0 <sup>6</sup> (3.60) 134.33 <sup>ab</sup> (17.38) 2.47 <sup>a</sup> (0.29) 50.00 <sup>ab</sup> ((16.82) 50.00 <sup>ab</sup> ((16.82) - 2.5% fat + 200 atmitine.
Nings         122.77 $^{*}(26.53)$ Full addomen carcass $1.96^{*}(0.19)$ Breast $687.09(457.51)$ Abdominal fat $33.11^{9}(14.27)$ Interaction Effects $642.00^{*}(10.5)$ Drumsticks $642.00^{*}(10.95)$ Neck $57.09(4.72)$ Nics $131.66^{*0}(20.5)$ Wings $131.66^{*0}(20.5)$ Breast $106^{*0}(20.5)$ Abdominal fat $48.33^{*0}(4.72)$ Negk L-carmitine: $70.43^{*0}(4.72)$ Wans with different superscripts with $90^{*0}(10.5)$	$\begin{array}{c} 124.56^{\circ}(8.1) \\ 1.78^{\circ}(0.53) \\ 698.33^{\circ}(14.16) \\ 45.58^{\circ}(14.16) \\ 772 \\ 1000^{\circ}(150.26) \\ 49.33^{\circ}(1.65) \\ 120.66^{\circ 0}(16.77) \\ 2.09^{\circ 0}(0.69) \\ 62.00^{\circ}(152.33) \\ 34.66^{\circ}(4.16) \\ 34.66^{\circ}(4.16) \\ 34.66^{\circ}(4.16) \\ 120.66^{\circ}(1.16) \\ 12$	$\begin{array}{c} 128 \ 00^{\circ}(7.38) \\ 702 \ 40^{\circ}(3.60) \\ 51.55^{\circ}(12.08) \\ \overline{597, 33^{\circ}(12.08)} \\ \overline{597, 33^{\circ}(5.79)} \\ 52.66^{\circ}(5.03) \\ 116.00^{\circ}b(2.64) \\ 1.82^{\circ}b(0.12) \\ 691.66^{\circ}(62.64) \\ 1.6.33^{\circ}(1.52) \\ 691.65^{\circ}(62.64) \\ 1.52^{\circ}b(1.2) \\ 1.$	T4 694.66*(48.18) 59.66*(6.65) 1.63*(0.41) 1.63*(0.41) 708.66*(93.55) 49.33*(7.50) 49.33*(7.50) 49.33*(7.50) apkg L-carritine fer significantly	$\begin{array}{c} 120^{40}(0.3,87)\\ 1.90^{40}(0.3,55)\\ 704,44^{40}(0.2,13)\\ \overline{517,33^{40}(1,37)}\\ \overline{577,33^{40}(1,37)}\\ \overline{577,33^{40}(1,27)}\\ \overline$	118 00°(14,60) 1.928°(0,43) 656.11°(16.36) 656.11°(16.36) 709.33°(57.93) 709.33°(57.93) 51.00°(4.35) 1.74 <sup>ab</sup> (0.53) 735.66°(53) 735.66°(28) 735.66°(28) 735.66°(28) 735.66°(28) 74.2200 mg/kg L-carn	2.01*(046) 2.01*(046) 730.25*(46.81) 34.02*(46.81) 730.25*(34.81) 668.33*(3.51) 59.33*(1.52) 2.09*b(0.36) 700.33*(1.52) 2.09*b(0.36) 77.00*(14.00) 57.00*(14.00) 57.00*(14.00)	T8 (529,00%(103,01) 56,33 <sup>4</sup> (6,42) 1,95 <sup>46</sup> (0,37) 66,266 <sup>4</sup> (5,85) 42,66 <sup>46</sup> (5,85) 61,0,37) 62,66 <sup>4</sup> (5,85) 42,66 <sup>46</sup> (5,85) 42,66 <sup>40</sup> (5,85)42,66 <sup>40</sup> (5,85) 42,66 <sup>40</sup> (5,85)42,66 <sup>40</sup> (5,85)42,66 <sup>40</sup> (5,85)42,6	T9 $\frac{T9}{52.0^{9}(3.60)}$ $52.0^{9}(3.60)$ $134.33^{3b}(17.38)$ $2.47^{9}(0.29)$ $75.3.3^{3}(3.02)$ $75.3.3^{3}(3.02)$ -2.5% fat + 200 armitine.
$\begin{array}{c c} Breast & 687.00^{\circ}(57.51) \\ Abdominal fat & 33.11^{\circ}(14.27) \\ Interaction Effects & 33.11^{\circ}(14.27) \\ Neck & 57.00^{\circ}(7.00) \\ Neck & 131.66^{\circ}(26.53) \\ Nings & 131.66^{\circ}(26.53) \\ Breast & 131.66^{\circ}(0.51) \\ Breast & 704.33^{\circ}(57.51) \\ Breast & 704.33^{\circ}(57.51) \\ Abdominal fat & 48.33^{\circ}(4.72) \\ I ( control) - 0\% fat + 0 mg/kg L-carnit \\ ng/kg L-carnitine; T6 - 2.5\% fat + 400 \\ hems with different superscripts with \\ hears with \\ hears with different superscripts with \\ hears with \\ hears with \\ hears \\ hear$	698.33*(38.00) 45.55*(14.16) 122 49.33*(4.16) 120.66 <sup>w</sup> (16.77) 2.09 <sup>4w</sup> (1.67) 34.66 <sup>w</sup> (4.16) me; T2 – 0% fat + ugkg L-carnitine; n each row of dict	705.44°(3.60) 51.55°(12.08) 73 597.33°(75.79) 52.66°(5.03) 116.00°b(2.64) 116.00°b(2.64) 118.20°b(0.12) 691.66°(62.64) 16.3.3°(1.52) 691.66°(62.64) 16.3.3°(1.52) 691.66°(62.64) 17.7 - 5% fat + 0 arr ary treatments dif	T4 694.66°(48.18) 59.66°(6.65) 1.63°(0.41) 1.63°(0.41) 708.66°(93.55) 49.33°(7.50) anitine; T3 – 0% f mitine; T3 – 0% f nitine; T3 – 0% f parentheses) of l	704.44*(62.13) 51.55*(9.24) 75 577.33*(61.37) 51.00*(8.71) 109.00*(11.26) 109.00*(112.6) 109.00*(112.6) 109.00*(22.6) 51.66*(22.6) 51.66*(22.6) 51.66*(22.6) 51.66*(22.6) 51.65*(22.6) at P.0.05 at P.0.5 at	656.11*(106.36) 44.66 <sup>ab</sup> (14.16) 709.33*(57.93) 51.00*(4.35) 10.66*(0.81) 1.746*(0.81) 35.66 <sup>ab</sup> (2.88) 35.66 <sup>ab</sup> (2.88) .cermtime: T4 – 2 200 mg/kg L-carn	730.22*(46.81) 34.00%(16.95) 668.33*(35.83) 59.33*(3.51) 125.33*(1.52) 2.03*(0.36) 700.33*(57.72) 57.00%(14.00) 57.00*(14.00) 57.00*(14.00) 14.00k fatter of dietary	T8 629.00°(103.01) 56.33*(6.42) 124.33*(15.88) 124.33*(15.88) 124.66*(5.88) 662.66*(5.83) 42.66*(5.85) g L-carnitine; T5 t + 400 mg/kg L-c t + 400 mg/kg L-c	T9 681.00%(62.95) 52.0°(3.60) 134.33%(17.38) 2.47%(0.29) 50.00 <sup>th</sup> (16.82) 50.00 <sup>th</sup> (16.82) armitine.
Interaction EffectsT1Drumsticks $642.00^{\circ}(1.09.57)$ Neck $57.00^{\circ}(7.00)$ Wings $131.66^{\circ}(2.6.3)$ Fualt abdomen carcass $1.96^{\circ}(0.19)$ Breat $704.33^{\circ}(7.21)$ Abdominal fat $48.33^{\circ}(4.72)$ Tl (control) - 0% fat + 0 mg/kg L-carnitng/kg L-carnitine; T6 - 2.5% fat + 400 ing/kg L-carnitine; T6 - 2.5% fat +	T2 $(660.00^{4}(50.26)$ (4.16) $(120.66^{ab}(16.77)$ $(5.0)^{ab}(0.69)$ $(5.0)^{ab}(0.53)$ (5.2.33) (4.16) (4.	T3 $597,33^{4}(75,79)$ $52,66^{6}(5,03)$ $116.00^{ab}(2,64)$ $1,82^{ab}(0,12)$ $691.66^{a}(62,64)$ $16.33^{c}(1,52)$ $15.35^{c}(1,52)$ 127-5% fat + 0 n ary treatments dif	T4 694.66*(48.18) 59.66*(6.65) 124.00 <sup>4b</sup> (3.60) 1.63*(0.41) 7.03*(0.41) 7.35*(7.35.05) 49.33a*(7.35.05) 1.63*(7.35.05)1.63*(7.35.05) 1.63*(7.35.05)1.63*(7.35.05)1.63*(7.35.05)1.63*(7.35.05)1.63*(7	$\begin{array}{c} TS \\ 577.33^{4}(61.37) \\ 51.00^{9}(8.71) \\ 109.00^{9}(11.26) \\ 1.74^{40}(0.22) \\ 640.66^{6}(129.24) \\ 51.66^{6}(129.24) \\ 51.66^{6}(129.24) \\ 1.81 + 400 \text{ mg/kg I} \\ 1.81 - 80^{5} \text{ fat } + 3 \\ 1.81 - 80^{5} $	T6 709.33*(57.93) 51.00°(4.35) 1.0.66*(9.81) 1.74 <sup>4b</sup> (0.53) 745.66*(2.88) 75.66*(2.88) 25.66*(2.88) 200 mg/kg L-carn	T7 668.33 <sup>a</sup> (38.83) 59.33 <sup>a</sup> (1.51) 125.33 <sup>a</sup> (1.52) 2.09 <sup>ab</sup> (0.36) 77.03 <sup>a</sup> (14.70) 57.00 <sup>a</sup> (14.00) 57.00 <sup>a</sup> (14.00) 57.0 <sup>b</sup> (14.00) 10 <sup>a</sup> k at + 0 mg/k titine; T9 - 5% fat	T8 (2900°(103.01) 56.33°(6.42) 1.24.33 <sup>th</sup> (15.88) 1.93 <sup>th</sup> (0.37) 66.26 <sup>th</sup> (8.60) 42.66 <sup>th</sup> (5.85) g L-carnitine; T5 t + 400 mg/kg L-c	T9 $(881.00^{9}(62.95))$ $52.0^{6}(3.60)$ $1.34.33^{36}(17.38)$ $2.47^{9}(0.22))$ $50.30^{39}(3.62)$ $50.30^{39}(3.62)$ $-2.5\%$ fat $+200^{6}$ (16.82) $-2.5\%$ fat $+200^{6}$ (16.82) -2.5% (16.82) $-2.5\%$ fat $+200^{6}$ (16.82) -2.5% (17.82) -2.5%
Drumsticks $642.00^{\circ}(109.57)$ Neck $57.00^{\circ}(7.00)$ Wings $13.06^{\circ}(0.26.53)$ Full abdomen carcass $11.96^{\circ}(0.19)$ Breast $704.33^{\circ}(57.51)$ Abdominal fat $48.33^{\circ}(57.51)$ Totor of the transition of tr	$r 660.00^{\circ}(50.26)$ 49.33'(4.16) 120.6 $^{00}(16.77)$ 2.09 $^{00}(16.77)$ 665.00°(152.33) 34.66 $^{00}(152.33)$ ne; T2 – 0% fat + ugkg L-camitine; n each row of dict n each row of dict	597.33 $^{a}$ (75.79) 52.66 $^{a}$ (5.03) 116.09 $^{ab}$ (2.64) 1.82 $^{ab}$ (0.12) 691.66 $^{b}$ (62.64) 16.33 $^{c}$ (1.52) 16.33 $^{c}$ (1.52) 16.33 $^{c}$ (1.52) ary treatments dif	694.66*(48.18) 59.66*(6.65) 1.24.00*(5.60) 1.63*(0.41) 708.66*(93.55) 49.33*(7.50) anitine; T3 – 0% fi nitine; T3 – 0% fi nitine; T3 – 0% fi natitine fer significantly	577.33*(61.37) 51.00*(8.71) 1.74th(0.25) 640.667(129.24) 51.66ab(22.67) 51.66ab(22.67) at P<0.05, at P<0.05. Ross 308 male br	709.33*(57.93) 51.00*(4.35) 10.66*(9.81) 1.74*(0.53) 745.66*(38.00) 35.66**(2.88) 200 mg/kg L-carn	668.33*(38.83) 59.33*(1.52) 125.33*(1.52) 2.09*(0.36) 700.33*(57.72) 57.00*(14.00) 57.00*(14.00) 5% fat + 0 mg/k titne; T9 - 5% fat	629,00°(103.01) 56,33°(6.42) 124,33°(15.88) 1.95°(0.37) 662.66°(68.06) 42.66° <sup>ab</sup> (5.85) g L-carritine; T5 t + 400 mg/kg L-c	$681.00^{46}(2.95)$ $52.0^{73.60}(17.38)$ $2.47^{90}(2.20)$ $753.33^{30}(16.82)$ $50.00^{ab}(16.82)$ arritine. arritine. ne in the first sii
Neck 57.00 $(7.00)$ Wings 131.66 $^{40}(25.51)$ Breast 13.66 $^{40}(125.51)$ Breast 104.33 $^{40}(125.51)$ Abdominal fat 48.33 $^{40}(4.72)$ (control) $-0\%$ fat $+0$ mg/kg L-carnit rg/kg L-carnitine: T6 $-2.5\%$ fat $+400$ r Means with different superscripts with	$\begin{array}{l} 49.33'(4.16)\\ 120.66''(16.77)\\ 2.09''(16.77)\\ 34.66''s(4.16)\\ 166''s(4.16)\\ 165''r(4.16)\\ 165$	52.66°(5.03) 116.00°(2.64) 116.00°(2.64) 691.66°(62.64) 16.33°(1.52) 16.33°(1.52) 16.33°(1.52) 16.33°(1.52) 16.33°(1.52) 16.33°(1.52) 17.5% fat+0 n ary treatments dif	59.66°(6.65) 124.00°63.60) 128.06°(9.3.6) 49.33°(7.50) 11itine; T3 – 0% f nitine; T3 – 0% f ngkg L-carnitine fer significantly	51.00 <sup>4</sup> (8.71) 13.00 <sup>4</sup> (1.26) 17.46 <sup>4(1)</sup> (2.22) 640.66 <sup>4(1)</sup> (22.24) 51.66 <sup>40</sup> (22.67) at $+ 400$ mg/kg L at $P < 0.05$ . Ross 308 male br	51.00*(4.35) 140.66'(9.81) 1.74 <sup>ab</sup> (0.53) 35.66 <sup>ab</sup> (2.89) .earnitine: T4 - 2 200 mg/kg L-carn	59.33*(3.51) 125.33*(1.52) 2.09*(0.36) 700.33*(57.72) 57.00°(14.00) 57.00°(14.00) 57.00°(14.00) 11evels of fatt - 5% fat	56.33*(6.42) 124.33*(15.88) 124.33*(15.88) 662.66*(68.06) 42.66* <sup>th</sup> (5.85) g L-carnitine: T5 t + 400 mg/kg L-c t + and L-carniti	52.0*(3.60) 134.33*(17.38) 2.47*(0.29) 753.33*(3.05) 50.00 <sup>ab</sup> (16.82) arruitine. arruitine. in the first si
Wings 131.66 <sup>ab</sup> (26.53 Full abdomen carcass 1.30.60 <sup>ab</sup> (26.53 Breast 1.06 <sup>ab</sup> (2.12) Abdominal fat $704.33^{ab}(5.751)$ ( $704.33^{ab}(5.751)$ Abdominal fat $8.33^{ab}(4.72)$ ( $704.33^{ab}(5.751)$ ( $702.33^{ab}(5.751)$ (	120.66 <sup>ab</sup> (16,77) 209 <sup>ab</sup> (0,69) 65.00 <sup>b</sup> (152,33) 34.66 <sup>bc</sup> (4.16) ne; T2 $- 0^{bb}$ fat + ne; T2 $- 0^{bb}$ fat + ne; tr 2 - 0 <sup>bb</sup> fat +	116.00 <sup>mb</sup> (2.64) 118.2 <sup>mb</sup> (0.12) 691.66 <sup>a</sup> (62.64) 16.33 <sup>e</sup> (1.52) 200 mg/kg L-carr 177 – 5% fat + 0 n ary treatments dif andard errors (in	124.00 <sup>ab</sup> (3.60) 1.63 <sup>b</sup> (0.41) 708.6 <sup>a</sup> (9.3.55) 49.33 <sup>ab</sup> (7.50) ag/kg L-carnitine fer significantly	109.00 <sup>6</sup> (11.26) 1.74 <sup>ab</sup> (0.22) 640.6 <sup>6</sup> (2129.24) fat + 400 mg/kg L at P=0.05. at P=0.05. Ross 308 male br	140.66°(9.81) 1.74 <sup>ab</sup> (0.53) 745.66 <sup>ab</sup> (2.380) camitine: T4 – 2 200 mg/kg L-carn	125.33 <sup>ab</sup> (1.52) 2.09 <sup>ab</sup> (0.36) 700.36) 57.037(14.07) 57.03 <sup>a</sup> (14.07) 57.04 <sup>a</sup> (14.07) 5% fat + 0 mg/k titne; T9 - 5% fat	124.33 <sup>th</sup> (15.88) 1.95 <sup>th</sup> (0.37) 66.26( <sup>46</sup> (5.85) 4.2.66 <sup>th</sup> (5.85) g L-carnitine; T5 t + 400 mg/kg L-c t + 400 mg/kg L-c	$134.33^{m}(17.38)$ $2.47^{m}(0.29)$ $5.2.37^{m}(0.82)$ $50.00^{m}(16.82)$ -2.5% fat + 20 armitine.
-ull abdomen carcass 1.90 <sup>en</sup> (0.19) Breast 704.33 <sup>4</sup> (57.51) Abdominal fat $-$ 88.33 <sup>4</sup> (4.72) I (control) $-$ 0% fat $+$ 0 mg/kg L-carnit g/kg L-carnitine; T6 $-$ 2.5% fat $+$ 400 Means with different superscripts with	0.69, $0.69$ ) $0.65.00^{o}(152.33)$ $0.65.00^{o}(152.33)$ $0.66^{6v}(4.16)$ me; T2 $-0.9^{o}$ fat + ngkg L-camitine; n each row of dict n each row of dict	$691.68^{\circ}(62.64)$ $691.66^{\circ}(62.64)$ $16.33^{\circ}(1.52)$ 200  mg/kg L-carry ary treatments dift ary treatments dift and ard errors (in	1.65*(0.41) 708.66(93.55) 49.33a <sup>(1</sup> (7.50) ag/kg L-carnitine fer significantly narentheses) of I	1.74 <sup>m</sup> (0.22) 640.66 <sup>4</sup> (12.69 24) 51.66 <sup>m</sup> (12.69 25) fat + 400 mg/kg L e: T8 - 5% fat + 7 at P<0.05. Ross 308 male br	1.74 <sup>m</sup> (0.53) 745.66%(38.00) -camiine: 74 - 2 200 mg/kg L-carn zoilose fed differen	2.09 <sup>m</sup> (0.36) 700.33 <sup>a</sup> (57.72) 57.037 (14.00) .5% fat + 0 mg/k titne; T9 - 5% fat t levels of dietary	1.95 <sup>ar</sup> (0.37) 662.66 <sup>4</sup> (8.85) 42.666 <sup>4</sup> (5.85) g L-carnitine: T5 t + 400 mg/kg L-c t + 400 mg/kg L-c	$2.47^{\circ}(0.29)$ $753.33^{\circ}(3.05)$ $50.00^{ab}(16.82)$ -2.5% fat $+20:armitine.:armitine.$
Abdominal fat $104.5.57$ , $704.5.57$ , $725$ , $823.33^{ab}$ (4.72) (control) $-0\%$ fat $+0$ mg/kg L-carnit gkg L-carnitine: T6 $-2.5\%$ fat $+400$ f. Means with different superscripts with $-5.5\%$ fat $-2.5\%$ fat	$34.66^{we}(4.16)$ $34.66^{we}(4.16)$ ne; $T2 - 0\%$ fat + ngkg L-carnitine; n each row of dict reach row of dict	091.00°102.04) 16.33°(1.52) 200 mg/kg L-carr T7 – 5% fat + 0 n ary treatments dif tandard errors (in	$(0.5.00^{-}(9.33^{al}(7.50))$ applye $T = -0\%$ fingly $T = -0\%$ find the significantly for significantly for significantly natertheses) of 1	040.007(1.29.24) 51.66 <sup>ab</sup> (22.67) [at + 400 mg/kg I c; T8 – 5% fat + 5 at P<0.05. at P<0.05. Ross 308 male br	/42.007(35.00) 35.66 <sup>abc</sup> (2.88) carnitine; T4 – 2 200 mg/kg L-carn	$700.557.00^{\circ}(14.00)$ $57.00^{\circ}(14.00)$ (tine; T9 – 5% fat tine; t9 – 5% fat	002.007(08.00) 42.66 <sup>46</sup> (5.85) t + 400 mg/kg L-c f and L-carniti	(2.5.5.7(2.02)) (2.5.9)/(16.82)/(16.82) (2.5.9)/(16.82
1 (control) – 0% fat + 0 mg/kg L-carnit g/kg L-carnitine; T6 – 2.5% fat + 4001 Means with different superscripts with	ne; T2 – 0% fat + 1g/kg L-carnitine; n each row of diet organ means and s	200 mg/kg L-carr T7 – 5% fat + 0 n ary treatments dif tandard errors (in	nitine; T3 – 0% fi ng/kg L-carnitine fer significantly parentheses) of I	fat + 400 mg/kg L e: T8 – 5% fat + 2 at P<0.05. Ross 308 male br	-carnitine; T4 – 2 200 mg/kg L-carn soilers fed differer	5% fat + 0 mg/k tine; T9 – 5% fat t levels of dietary	g L-carnitine; T5 t + 400 mg/kg L-c fat and L-carniti	- 2.5% fat + 20 arnitine.
Main effects	Fat (%)		1	- ,	-carnitine (mg/kg			
0	2.5	5		0	200	400		
testine length (cm) $2.20^{a}(0.15)$	$2.29^{a}(0.20)$	$2.34^{a}(0.04)$	I	$2.21^{a}(0.14)$	$2.33^{a}(0.23)$	$2.28^{a}(0.12)$		
testine weight $(g)$ 94.11 <sup>b</sup> (11.01)	112.44 <sup>a</sup> (12.12)	$112.44^{a}(2.51)$		$104.88^{a}(12.49)$	$108.66^{a}(25.75)$	$115.44^{a}(16.21)$		
eart weight (g) 10.88 <sup>a</sup> (2.64)	$11.22^{a}(1.00)$	$11.33^{a}(1.52)$		$11.66^{a}(1.50)$	$10.33^{a}(2.54)$	$11.44^{a}(1.13)$		
iver weight (g) 54.11 <sup>a</sup> (9.64)	53.22 <sup>a</sup> (2.64)	$47.2^{a}(0.57)$		$51.22^{a}(10.33)$	$51.00^{a}(7.14)$	$52.33^{a}(5.78)$		
izzard weight (g) 35.88 <sup>a</sup> (2.64)	$37.11^{a}(1.52)$	$37.77^{a}(6.42)$	1	$38.00^{a}(1.93)$	35.33 <sup>a</sup> (3.57)	$37.44^{a}(4.36)$		
Interaction effects T1	T2	T3	T4	T5	T6	Τ7	T8	T9
testine length (cm) $2.14^{ab}(0.15)$	$2.13^{b}(0.11)$	$2.32^{ab}(0.08)$	$2.25^{ab}(0.19)$	$2.41^{ab}(0.29)$	$2.21^{ab}(0.20)$	$2.24^{ab}(0.10)$	$2.46^{a}(0.15)$	$2.32^{ab}(0.04)$
testine weight (g) 93.33°(11.01)	88.33°(6.80)	100.66 <sup>bc</sup> (7.37) 1	13.33 <sup>abc</sup> (11.93)	112.00 <sup>abc</sup> (27.87)	112.00 <sup>abc</sup> (12.12)	108.00 <sup>abc</sup> (64.24)	125.66 <sup>ab</sup> (27.57)	133.66 <sup>a</sup> (2.51)
cart weight (g) 12.00 <sup>a</sup> (2.64)	$9.00^{a}(2.64)$	$11.66^{a}(1.15)$	$12.00^{a}(0.00)$	$10.66^{a}(2.88)$	$11.00^{a}(1.00)$	$11.00^{a}(1.00)$	$11.33^{a}(2.51)$	$11.66^{a}(1.52)$
iver weight (g) 52.00 <sup>ab</sup> (9.64) izzard weight (g) 39.00 <sup>a</sup> (2.64)	$58.66^{a}(3.51)$ $33.66^{a}(2.30)$	$51.66^{ab}(10.96)$ $35.00^{a}(4.00)$	$57.66^{ab}(10.69)$ $38.00^{a}(2.00)$	$48.00^{ab}(3.60)$ $35.66^{a}(4.04)$	$54.00^{ab}(2.64)$ $37.66^{a}(1.52)$	$44.00^{b}(8.71)$ $37.00^{a}(1.00)$	$46.33^{ m ab}(6.65)$ $36.66^{ m a}(4.72)$	51.33 <sup>ab</sup> (0.57) 39.66 <sup>a</sup> (6.42)

BW gain during the initial growing phase, while in a more recent study an increase of growth rate and greater BW, feed intake and FCR in broilers fed supplemental 60 ppm L-carnitine were observed by Oladele *et al.* [2011]. Our results are in agreement with other studies [Rabie *et al.* 1997, Rabie and Szilágyi 1998, Xu *et al.* 2003, Rezaei *et al.* 2007], which reported the effect reducing abdominal fat content for L-carnitine provided at doses of 50-250 mg/kg. Our results showed that L-carnitine decreased the weight of the neck, although breast and drumstick weights were not significantly affected in contrast to other studies [Rabie and Szilágyi 1998, Xu *et al.* 2003], in which supplemental 50 mg/kg L-carnitine increased breast meat and drumstick weights. Data showed that L-carnitine improved fatty acid oxidation, prevented esterification to triglycerides and fat storage in the abdomen.

## Interaction effects

Data on the growth performance of broilers fed different diets are summarized in Table 2. No significant variations were observed between the different groups of feed supplementation and breeding parameters, i.e. FCR and BW. The EPEF was generally higher in the group receiving 5% fat + 200 mg/kg L-carnitine (P<0.05) compared to the control group and the group fed supplemental 400 mg/kg L-carnitine alone (P<0.05), in which EPEF was the lowest. The supplemented diet modified significantly the spleen weight (Tab. 3), which was greater in the group fed 2.5% fat + 400 mg/kg L-carnitine (P<0.05) than in the group fed the high fat (5%) diet with 200 mg/kg L-carnitine (P<0.05).

Of carcass components (Tab. 4), supplemental 5% fat + 400 mg/kg L-carnitine increased significantly the full abdomen carcass weight (P<0.05), while it was the lowest in broilers fed the low fat diet alone (P<0.05). The maximum abdominal fat weight was obtained in chickens fed 5% fat alone (P<0.05). When compared to the effect of the diet supplemented with L-carnitine, we observed abdominal fat weight reduced by approx. 40% at its lower dose (200 mg/kg, P<0.05) and by nearly 70% at its higher dose (400 mg/kg, P<0.05). The low fat diet combined with 400 mg/ kg L-carnitine had a positive effect on the wings weight (P<0.05). The supplement of 200 mg/kg L-carnitine alone decreased the length and weight of the intestine (both P<0.05) when compared to the same dose supplementing the high fat diet. Moreover, the heaviest intestines were found in broilers fed the high fat diet with the higher L-carnitine dose compared to the controls and birds fed the lower dose of L-carnitine alone. We also found that the livers were heavier in the group fed with supplemental 200 mg/kg L-carnitine alone compared to the group fed the high fat diet alone.

Of the blood parameters (Tab. 6), the level of serum triglycerides (P<0.05) was altered depending on the dietary treatments. In general, formulations containing 400 mg/kg L-carnitine provided a greater reduction of plasma triglycerides. In contrast, the highest triglyceride level was observed in broilers receiving 200 mg/kg L-carnitine in the low fat diet (P<0.05). There were no significant variations in the other parameters

of age									
Main effects		Fat (%)			I	J-carnitine (mg/kg	g)		
	0	2.5	5		0	200	400		
DBIL (mg/dl)	$0.66^{a}(0.00)$	$1.00^{a}(0.82)$	$0.48^{a}(0.17)$		$0.52^{a}(0.48)$	$0.44^{a}(0.26)$	$1.01^{a}(0.83)$		
TBIL (mg/dl)	$1.75^{a}(0.37)$	$2.01^{a}(0.90)$	$1.72^{a}(0.51)$		$1.80^{a}(0.73)$	$1.74^{a}(0.74)$	$2.03^{a}(0.93)$		
ALP (mg/dl)	$422.00^{a}(72.85)$	$405.00^{a}(35.67)$	$374.89^{a}(41.94)$		$379.44^{a}(48.47)$	448.78 <sup>a</sup> (174.31)	393.78 <sup>a</sup> (32.53)		
AST (U/I)	$270.33^{a}(25.57)$	$293.67^{a}(32.33)$	261.78 <sup>a</sup> (36.47)		279.33 <sup>a</sup> (37.37)	286.33 <sup>a</sup> (35.65)	268.11 <sup>a</sup> (31.02)		
CREA (mg/dl)	$0.32^{a}(0.00)$	$0.33^{a}(0.05)$	$0.30^{a}(0.00)$		$0.30^{a}(0.00)$	$0.33^{a}(0.07)$	$0.32^{a}(0.04)$		
BUN (mg/dl)	$1.05^{a}(0.00)$	$1.67^{a}(1.51)$	$1.11^{a}(0.72)$		$0.11^{a}(0.05)$	$1.28^{a}(0.66)$	$1.50^{a}(1.03)$		
LDL (mg/dl)	$60.55^{a}(1.52)$	$58.22^{a}(3.78)$	$57.66^{a}(6.11)$		$58.33^{a}(4.63)$	$59.00^{a}(5.29)$	$59.11^{a}(0.25)$		
HDL (mg/dl)	$71.22^{a}(4.16)$	$66.55^{a}(4.58)$	$66.55^{a}(9.29)$		$67.22^{a}(5.65)$	$69.77^{a}(5.73)$	$67.33^{a}(7.14)$		
TG (mg/dl)	$73.56^{a}(5.05)$	$97.67^{a}(9.45)$	76.21 <sup>a</sup> (16.86)		78.22 <sup>a</sup> (15.24)	$101.78^{a}(8.17)$	$67.44^{a}(10.64)$		
CHOL (mg/dl)	$138.67^{a}(31.77)$	$138.00^{a}(9.50)$	$143.89^{a}(37.46)$		$139.00^{a}(28.19)$	$134.67^{a}(20.89)$	$146.89^{a}(28.45)$		
Glucose (mg/dl)	259.33 <sup>a</sup> (18.61)	$250.88^{a}(6.35)$	255.55 <sup>a</sup> (13.65)		$250.88^{a}(19.12)$	$260.77^{a}(22.57)$	254.11 <sup>a</sup> (23.67)		
Interaction effects	TI	T.	Ţ	Τ4	Τs	Τƙ	T7	TR	T9
DBIL (mø/dl)	$0.30^{a}(0.00)$	$0.30^{a}(0.00)$	$1.40^{a}(0.95)$	$0.83^{a}(0.83)$	$0.40^{a}(0.10)$	$1.23^{a}(1.00)$	$0.43^{a}(0.15)$	$0.63^{a}(0.41)$	$0.40^{a}(0.17)$
TBIL (mø/dl)	$1.36^{a}(0.38)$	$1.30^{a}(0.44)$	$2.60^{a}(1.15)$	2.13 <sup>a</sup> (1.19)	$2.06^{a}(0.64)$	$2.10^{a}(0.90)$	$1.90^{a}(0.36)$	$1.86^{a}(1.06)$	$1.40^{a}(0.51)$
ALP (mg/dl)	401.66 <sup>a</sup> (72.85)	529.33 <sup>a</sup> (278.50)	395.00 <sup>a</sup> (15.00)	$375.00^{a}(25.11)$	$429.00^{a}(41.39)$	$411.00^{a}(35.67)$	361.66 <sup>a</sup> (47.05)	$388.00^{a}(90.14)$	$375.00^{a}(41.94)$
AST (U/I)	281.66 <sup>a</sup> (25.57)	$283.33^{a}(50.33)$	$246.00^{a}(10.39)$	299.66 <sup>a</sup> (53.87)	296.66 <sup>a</sup> (39.71)	284.66 <sup>a</sup> (32.33)	256.66 <sup>a</sup> (25.16)	$279.00^{a}(26.85)$	$249.66^{a}(36.47)$
CREA (mg/dl)	$0.30^{a}(0.00)$	$0.33^{a}(0.06)$	$0.33^{a}(0.06)$	$0.30^{a}(0.00)$	$0.36^{a}(0.11)$	$0.33^{a}(0.05)$	$0.30^{a}(0.00)$	$0.30^{a}(0.00)$	$0.30^{a}(0.00)$
BUN (mg/dl)	$1.00^{a}(0.00)$	$1.16^{a}(0.29)$	$1.00^{a}(0.00)$	$1.06^{a}(0.11)$	$1.66^{a}(1.15)$	$2.30^{a}(1.51)$	$1.10^{a}(0.17)$	$1.03^{a}(0.05)$	$1.20^{a}(0.72)$
LDL (mg/dl)	$(61.33^{a}(1.52))$	$60.00^{a}(5.52)$	$60.33^{a}(5.03)$	$57.66^{a}(5.85)$	$55.33^{a}(6.65)$	$61.66^{a}(3.78)$	$56.00^{a}(5.19)$	$61.66^{a}(2.08)$	$55.33^{a}(6.11)$
HDL (mg/dl)	$71.33^{a}(4.16)$	$71.00^{a}(8.19)$	$71.33^{a}(7.23)$	$66.33^{a}(7.02)$	$66.33^{a}(5.50)$	$67.00^{a}(4.58)$	$64.00^{a}(4.35)$	$72.00^{a}(2.64)$	$63.66^{a}(9.29)$
TG (mg/dl)	$132.33^{ab}(31.77)$	$81.00^{ab}(7.00)$	$(64.33^{b}(7.23))$	$75.66^{ab}(10.06)$	149.66 <sup>a</sup> (115.50)	67.66 <sup>b</sup> (9.45)	83.66 <sup>ab</sup> (27.13)	$74.66^{ab}(3.51)$	$70.33^{b}(16.86)$
CHOL (mg/dl)	$132.33^{a}(31.77)$	$125.33^{a}(20.65)$	$158.33^{a}(20.41)$	138.66 <sup>a</sup> (14.74)	$150.00^{a}(26.45)$	$125.33^{a}(9.50)$	$146.00^{a}(42.57)$	$128.66^{a}(9.07)$	$157.00^{a}(37.46)$
Glucose (mg/dl)	247.33 <sup>a</sup> (18.61)	$258.33^{a}(13.20)$	272.33 <sup>a</sup> (33.26)	$239.33^{a}(10.06)$	275.66 <sup>a</sup> (35.01)	$237.66^{a}(6.35)$	$266.00^{a}(21.28)$	$248.33^{a}(8.02)$	$252.33^{a}(13.65)$
DBIL – direct bilirubii lipopreins; HDL – hi fat + 400 mg/kg L-carr carnitine; T8 – 5% fat-	<ul> <li>a; TBIL – total bili</li> <li>igh density lipoprot</li> <li>initine; T4 – 2.5% fi</li> <li>+ 200 mg/kg L-car</li> </ul>	rubin; ALP – alka teins; TG – triglyc at + 0 mg/kg L-cai mitine; T9 – 5% fa	line phosphatase. cerides; CHOL – mitine; T5 – 2.5% at + 400 mg/kg L	AST – aspartate cholesterol; T1 (c 6 fat + 200 mg/k; carnitine.	amino transferase control) – 0% fat + g L-carnitine; T6 -	;; CREA – creatin + 0 mg/kg L-carni - 2.5% fat + 400 1	nine; BUN – blooc itine; T2 – 0% fat mg/kg L-carnitine	l urea nitrogen; L + 200 mg/kg L-c: ;; T7 – 5% fat + 0	DL – low density arnitine; T3 – 0% mg/kg L-
<sup>au</sup> Means with different	superscripts within	n each row of aleu	ary treatments on	tter significanuly a	at P<0.05.				

of organs and blood. The current results indicated that supplemental L-carnitine has performance-improving and lipolytic effects in broiler chickens fed applying different fat levels, which are consistent with those reported in other studies [Rabie and Szilágyi 1998, Parsaeimehr *et al.* 2014].

The European Production Efficiency Factor (EPEF) is a simple and practical index to assess productive performance data, which was increased up to 349 in the group receiving 5% fat, suggesting that dietary supplementation may improve growth performance. Similar data were found in broilers fed diets containing probiotics [360, Biernasiak and Slizewska 2009]. We observed no response of FCR and BW during the experimental period, which is in line with findings of Murali et al. [2015], who used 900 mg/kg L-carnitine in a high fat diet of chickens. It contradicts findings of other studies, which reported a reducing [Rajabzadeh-Nesvan et al. 2013] or improving effect [Jalali et al. 2015] of L-carnitine supplementing different fat source diets on FCR, at increased BW and feed intake in chickens [Rajabzadeh-Nesvan et al. 2013, Jalali et al. 2015]. The weights of wings, spleen, intestine, liver, abdomen as well as intestine length were significantly increased in response to the experimental diets, which was attributable to the L-carnitine effect in a fat rich diet as a result of increasing energy efficiency of dietary fat. Our results are in line with the study of Rezaei et al. [2007] that revealed the same effect on the liver weight in broilers fed a combined diet. In contrast, Rajabzadeh-Nesvan et al. [2013] reported no significant effect of such a diet on the weight of the heart, liver, breast and thighs.

Energy requirements increase in the first period of broiler growth. Carnitine, as an essential compound in energy metabolism, facilitates the transport of fatty acids into the mitochondrial matrix mobilizing energy for cells [Furuno et al. 2001]. Elevated cellular energy utilization results in an increased metabolic rate, which makes the availability of L-carnitine particularly critical [Buyse et al. 2001]. Highenergy intake generates higher serum levels of triglycerides and cholesterol as well as greater deposition of fat in the body [Parsaeimehr et al. 2014] as was reported in our study. Therefore, additional L-carnitine is favorable [Buyse et al. 2001]. We found a decrease in the abdominal fat weight and serum triglycerides at the higher (400 mg/ kg) L-carnitine dose, while the other blood parameters were not affected. Arslan et al. [2004] reported lowered serum triglycerides, but also cholesterol and total lipids in Japanese quails. By contrast, a low dose of dietary L-carnitine (60 mg/kg) increased cholesterol levels [Kheiri et al. 2011]. Moreover, there are reports on hypoglycaemic effects of L-carnitine in broilers [Buyse et al. 2001, Wang et al. 2013] and when given together with fat, resulting in markedly reduced cholesterol and LDL levels [Parasaeimehr et al. 2013]. However, Jalali et al. [2015] reported increased levels of cholesterol, HDL, LDL, and proteins in the serum of broiler chickens.

The results obtained in this study revealed that 400 mg/kg dietary L-carnitine markedly lower abdominal fat weight and serum triglycerides levels at no addition of fat to the diet. Feeding the high fat diet supplemented with 200 mg/kg L-carnitine showed the highest EPEF. Overall, the performance traits improved with the increase

in the fat inclusion level. It can be concluded that dietary L-carnitine improved growth performance of broilers, thus it may be a promising way to reduce fat storage in broilers and improve the quality of carcasses intended for human consumption.

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