EFFECT OF UNSATURATED TO SATURATED FATTY ACID RATIO OF SUPLLEMENTAL FAT WITH OR WITH OUT L-CARNITINE ON PERFORMANCE AND CARCASS TRAITS IN BROILER CHICKEN

BY

CH. LEELA SWARNA
B.V.Sc. & A. H

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CERTIFICATE

Mrs. CH. LEELA SWARNA has satisfactorily prosecuted the course of research and that the thesis entitled **"EFFECT OF UNSATURATED TO SATURATED FATTY ACID RATIO OF SUPLLEMENTAL FAT WITH OR WITH OUT L-CARNITINE ON PERFORMANCE AND CARCASS TRAITS IN BROILER CHICKEN"** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by her for a degree of any university.

Date: 9 -2-2009
Place: Hyderabad

(Dr. S. QUDRATULLAH)
MAJOR ADVISOR

CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF UNSATURATED TO SATURATED FATTY ACID RATIO OF SUPLLEMENTAL FAT WITH OR WITH OUT L-CARNITINE ON PERFORMANCE AND CARCASS TRAITS IN BROILER CHICKEN"** submitted in partial fulfillment of the requirements for the degree of **MASTER OF VETERINARY SCIENCE** in **POULTRY SCIENCE** of **Sri Venkateswara Veterinary University, Tirupati**, is a record of the bonafide research work carried out by **Mrs. CH. LEELA SWARNA** under my guidance and supervision. The subject of the thesis has been approved by the student's Advisory Committee.

No part of the thesis has been submitted by the student for any other degree or diploma or has been published. The published part has been fully acknowledged. All the assistance and help received during the course of investigation have been duly acknowledged by the author of the thesis.

(Dr. S. Qudratullah)
Chairman of the Advisory Committee

Thesis approved by the Student's Advisory Committee

Chairman: **(Dr. S. Qudratullah)**
Professor and University Head
Department of Poultry Science
College of Veterinary Science
Rajendranagar, Hyderabad 500 030 ----------

Member: **(Dr. V. Ravinder Redddy)**
Professor
Department of Poultry Science
College of Veterinary Science
Rajendranagar, Hyderabad 500 030 ----------

Member: **(Dr. S. V. Rama Rao)**
Senior Scientist
Project Directorate on Poultry
Rajendranagar, Hyderabad 500 030 ----------

CONTENTS

List of Tables

List of Figures

DECLARATION

I, **Mrs. CH. LEELA SWARNA**, hereby declare that the thesis entitled **"EFFECT OF UNSATURATED TO SATURATED FATTY ACID RATIO OF SUPLLEMENTAL FAT WITH OR WITH OUT L-CARNITINE ON PERFORMANCE AND CARCASS TRAITS IN BROILER CHICKEN"** submitted to **Sri Venkateswara Veterinary University, Tirupati** for the degree of **MASTER OF VETERINARY SCIENCE** is the result of original research work done by me. I further declare that the thesis or part thereof has not been published earlier elsewhere in any manner.

Date : 9 -2-2009 **(CH. LEELA SWARNA)**
Place : Hyderabad

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LIST OF ABBREVIATIONS

<	:	lesser than
>	:	greater than
≥	:	greater than or equal to
%	:	percentage
Σ	:	sum
α	:	alpha
β	:	beta
ADFI	:	average daily feed intake
ADG	:	average daily gain
AFP	:	abdominal fat pad
ATP	:	adenosine triphosphate
C	:	carbon
CLA	:	conjugated linoleic acid
CoA	:	co-enzyme A
CSBO	:	crude soybean oil
FCR	:	feed conversion ratio
Fe (II)	:	ferrous iron
FI	:	feed intake
g	:	gram
hrs	:	hours
kcal	:	kilocalories
kg	:	kilogram
l	:	liter
L-car	:	L-carnitine
LD	:	levo and dextrose form

LPL	:	lipoprotein lipase
ME	:	metabolizable energy
mg	:	milligram
mg/dl	:	milligram per deci liter
ml	:	milliliter
mmol/l	:	milli mole per liter
MUFA	:	monounsaturated fatty acids
n-3	:	omega -3 fatty acids
n-6	:	omega-6 fatty acids
^{o}c	:	degree centigrade
ppm	:	parts per million
PUFA	:	polyunsaturated fatty acids
R to C	:	ready to cook
SBO	:	soybean oil
SFA	:	saturated fatty acids
TAL	:	tallow
UFA	:	unsaturated fatty acids
µm	:	micro meter
µmol/l	:	micro mole per liter
v/v	:	volume per volume
WG	:	weight gain
w/w	:	weight per weight

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ABSTRACT

The present experiment was conducted to study the effects of fat sources and the ratio of unsaturated to saturated fatty acids (60:40, 65:35, 70:30 and 75:25), with or without L-carnitine supplementation in a 6 x 2 factorial manner on the performance, carcass yield and serum lipid profile of male broiler chicks. A total of 480 day old male broiler chicks were divided into 12 treatments with eight replicate and five birds each and fed test diet till six weeks of age. Before the feed formulation, the lipid profile of the tallow and crude soybean oil were analyzed by Agilent technologies 6890N Gas chromatography. The UFA : SFA ratio were found to be 5.37 and 0.77 respectively for CSBO and tallow. Data was analyzed by General Linear Model producer of Statistical Package for Social Sciences.

Body weight gain was significantly ($P<0.05$) higher for birds fed crude soybean oil than tallow during starter and overall period. During finisher phase body weight gain was significantly ($P<0.05$) higher for carnitine supplemented groups. Interaction between fat source and carnitine was significant. Feeding of broilers with crude soybean oil with carnitine caused an increase in the body weight gain and tallow with carnitine caused a decrease in the body weight gain. Among the ratios of UFA: SFA, significantly ($P<0.05$) the highest weight gain was observed at 70: 30 ratio for starter, finisher and overall period. However, carnitine

supplementation to these ratios did not have significant (P>0.05) effect on weight gain during the finisher and the overall period.

The fat source did not have significant (P>0.05) effect on feed intake during the overall period. Whereas supplementation of carnitine has significantly (P<0.05) lowered feed intake during the overall period. Interaction effect was significant during the finisher and the overall period.

FCR was significantly (P<0.05) better for crude soybean oil during the starter and the overall periods. Inclusion of carnitine significantly (P<0.05) improved FCR during starter, finisher and overall periods. Significantly (P<0.05) better FCR was observed at 60:40 ratio and diets without carnitine supplementation. The interaction effect was significant (P<0.05) only during starter phase.

The fat source and UFA: SFA ratio with or without carnitine did not have significant (P>0.05) effect on various carcass yields studied except for abdominal fat percentage, where interaction between fat source and carnitine was significant (P<0.05). Abdominal fat content was significantly (P<0.05) low for crude soybean oil without carnitine. Among the ratios, significantly (P<0.05) higher abdominal fat deposition was found at 60:40 UFA: SFA ratio. With respect to UFA: SFA ratio diets, carnitine supplementation significantly reduced deposition of abdominal fat at 70:30 ratio while other ratios remained unaffected.

Liver moisture content was significantly (P<0.05) higher for tallow diets and at 60:40 ratio of UFA: SFA. Carnitine supplementation has significantly (P<0.05) increased moisture percentage of liver in case of fat source. Significantly (P<0.05) higher moisture content of light muscle was observed at 65:35 and 75:25, whereas for dark muscle it was observed at 70:30 ratio. Carnitine supplementation to UFA: SFA diets significantly (P<0.05) increased moisture content of dark muscle, whereas in light muscle it resulted in significant (P<0.05) reduction of moisture percentage. The interaction effect was significant for light and dark muscles and liver.

Fat content in liver and light muscle was significantly ($P<0.05$) lower for tallow and crude soybean oil and for UFA: SFA ratio at 75:25 and 70:30 ratio respectively. Carnitine supplementation significantly ($P<0.05$) increased fat content of liver, light and dark muscles except at UFA: SFA ratios for liver and light muscle, where there was significant ($P<0.05$) decrease in fat deposition by carnitine supplementation.

Serum triglycerides concentration was significantly low ($P<0.05$) for bird fed crude soybean oil and 70: 30 ratio of UFA: SFA at 12 hrs fasting whereas, the concentration of triglycerides and cholesterol at 3hrs fasting was significantly ($P<0.05$) low for birds fed with tallow diet and at 65:35 UFA: SFA ratio. Carnitine supplementation reduced significantly ($P<0.05$) serum triglyceride and cholesterol for fat source and UFA: SFA ratios.

Thus it can be concluded that for fat source body weight gain, FCR and carcass quality traits (abdominal, light and dark muscle fat percentage) were better for CSBO with carnitine and CSBO without carnitine respectively. In case of ratio of UFA: SFA, better body weight gain and FCR were observed at 70:30 and 60:40 ratios of UFA: SFA without carnitine respectively. However, lean meat was obtained at 70:30 ratio with carnitine.

CHAPTER I

INTRODUCTION

Addition of fats and oils in poultry ration is a usual practice and a must to meet the higher energy requirement of broilers for sustaining the growth potential of superior germ plasm. The use of the cheapest form of energy in order to minimize the feed cost is a wise option for accelerating profits in poultry industry. The energy source should produce the greatest growth rate per unit cost. The fats/oils are referred to as a source of concentrated energy and fatty acids included in the diet increase the amount of energy provided to the bird, which causes increased feed efficacy thus reducing the feed cost.

The amount of energy contributed by fats depends upon degree of saturation and chain length, location of free fatty acid in the glycerol molecule and proportion of free fatty acids (Wiseman, 2003). Based on fatty acid composition, it is possible to manipulate the amount of energy provided in the poultry diet. Most of the vegetable oils containing unsaturated fatty acids are highly digestible than animal fat sources and are therefore better source of energy for poultry. Soybean oil is the most widely used energy source contributing to more than half (58%) of the total dietary fat sources under usage, while palm kernels and copra oil (2%) are the least used. Among animal fat sources fish oil and poultry fat contain highest metabolic energy value (9000 kcal/kg) as they are rich in unsaturated fatty acids but their usage is limited because of the production of fishy odors in meat and are easily prone to oxidative rancidity (Poste, 1990).

Poultry meat is an accepted valuable source of nutrients for consumers who are interested in products enriched with beneficial components resulting in functional foods thus influencing one or more nutrients in a favorable way, exceeding the normal adequate nutrition (Grashorn, 2007). If these need to be popularized, the demand of consumers for lean meat has to be met.

Abdominal fat deposition was high for animal fat whereas it was low for vegetable oils. This difference in deposition of fat is mainly attributed to difference in fatty acid profiles of various fat/oil sources. The carcass fat percentage increases as the level of inclusion of fat/oil is increased in the diet. As the dietary ratio of SFA: UFA is decreased, abdominal fat deposition was found to be diminished in a dose dependent manner which was independent of amount of fat in the diet.

Several methods were employed to reduce fat content of carcass, by feeding organic chromium in birds which forms an active component of glucose tolerance factor, thus making the metabolic action of insulin more effective (Anandhi *et al*., 2006). Recently many reports showed that Conjugated Linoleic Acid (CLA) has potential ability to reduce fat deposition in the animal carcass (Ostrowska, 1999). Similarly using CLA with oils rich in n-3 fatty acids or in diets that have balanced ratio of n-6 and n-3 has optimized the effect of CLA and demonstrated linear reduction of lipid deposition in abdominal fat pad when canola oil was used with CLA, but the same effect was not seen when soybean oil was used.

Likewise several mechanisms are involved in lowering energy efficiency of unsaturated fatty acids. Preferentially oxidation of unsaturated fatty acids in peroxisomes prior to their oxidation in mitochondria leads to higher energy losses. This can be prevented by L-Carnitine supplementation.

Considering these aspects the present study was taken up with the following objectives:

1 To evaluate the fatty acid composition of crude soybean oil (Glycine max) and tallow.

2 To determine the optimum ratio of unsaturated to saturated fatty acids of supplemental blended oils for obtaining lower fat percentage in the liver, breast and thigh muscles and abdominal fat.

3 To study the role of supplemental L-carnitine on the performance of broilers besides reducing the fat.

4 To determine serum cholesterol and triglycerides in treatment groups.

CHAPTER II

REVIEW OF LITERATURE

2.1 Importance of fats and oil in poultry diet

The addition of fat to the diets, besides supplying energy, improves the absorption of fat-soluble substances by reducing the passage rate of the digesta in the gastrointestinal tract (Baiao and Lara, 2005), increases the plasma vitamin E and A (Abawi *et al.,* 1985) diminishes the pulverulence, decrease the wear and tear on milling machinery in feed mills, increases the palatability of the rations, and increases the efficiency of the consumed energy (lower caloric increment) besides providing essential fatty acids like linoleic, linolenic and arachdonic acids which can't be synthesized by the bird.

2.2 Distribution and composition of body lipids in broiler chicken

In broilers, the fat is stored as abdominal fat (from gizzard to the cloaca), fat around gizzard, fat located in sartorius muscle, fat located in neck (from shoulder to the head) and mesenteric fat (from the pylorus to the colon) accounting to 20% of total body lipids, skin and subcutaneous adipose tissue 18%, liver and feathers 2.5%, skeleton 15%, and rest of carcass 40% mainly in the form of triglycerides (Cahaner *et al.,*, 1986). According to Evans (1997) more than 85% of triacylglycerols are stored in adipose tissue and skin, where as breast contains 43% triglycerides and 55% phospholipids, and thigh contain about 85% triglycerides and 16% phospholipids. The lipids found in breast are mainly from the cellular membrane i.e., cholesterol and phospholipids whereas in thigh and skin, adipocytes are major components.

Accumulation of fat in abdominal adipose tissue 20 g/kg body weight and visceral areas 20% (Mourot and Hermier, 2001) is of great concern in broiler production since it is a waste product to consumers who are increasingly concerned about the nutritional and health aspects of their foods. Such obese broilers are unattractive to the consumers and thus will lead to decreased saleability, which in turn reduces the net returns for the producers (Hermier, 1997). Control of lipid deposition is a matter of increasing interest in poultry production.

2.3 Effect of supplemental fat on carcass fat and quality

The fat content of broiler carcass ranges between 13 to 14.5% (Havenstein *et al.,* 2003). Several factors affect fat deposition in chicken including genetics, sex, age, live weight and nutrition. Females are able to deposit more body fat than males (Pan *et al.,* 1979) and older chicken have higher fat content in the carcass compared to young chicken (Deaton and Lott, 1985). Both energy and protein are essential for growth and when there is alteration in the ratio of energy to protein, it may result in excessive fat accumulation.

Due to high growth rate of broilers, they have a higher requirement of energy and use of triglycerides as a major source may result in fatty carcass (Newman, 2000). Fatty carcass can be prevented by altering source of energy metabolism as glucose rather than triglycerides which can be achieved by dietary fatty acids. The changes in fatty acid composition of phospholipids of skeletal membrane can be brought by dietary means which is closely related to insulin action. Diets high in saturated fatty acids (SFA) or lower ratio of PUFA: SFA or higher ratio of n-6/n-3 leads to insulin resistance in both skeletal muscles and adipose tissues. Study conducted by Storlein (1991) in rats, demonstrated that diets with high level of n-6 series leads to overwhelming insulin resistance to many

tissues. As a result, organism utilizes triglycerides resulting in more fat accumulation in the tissues. Whereas, Newman (2000) reported feeding broilers with fish oil (n-3 fatty acids) instead of tallow or sunflower oil increased glucose uptake by the breast muscle thus reducing the bird's reliance on triglycerides, which consequently resulted in leaner carcass. Thus an increase in dietary PUFA: SFA ratio by the inclusion of n-3 fatty acids has direct effect on glucose and lipid metabolism thus decreasing body fat mass. In rats n-3 fatty acids reduces cell size of adipose tissue and also reduces the fat pad thickness (Azian 2004) and also in broilers, the adipocyte count decreases when fed with higher incorporation of unsaturated fats (Wongsuthavas, 2007a).

Polyunsaturated fatty acids (PUFA) apart from increasing insulin-sensitivity of muscle and adipose tissue, also plays an important role in the reduction of abdominal fat deposition by regulating the genes controlling the expression of enzymes involved in fatty acid synthesis and oxidation (Senz *et al.,* 2000a). Fatty acid synthetase, an important enzyme in the hepatic lipid biosynthetic pathway that controls *de novo* fatty acid synthesis is inhibited by both n-3 and n-6 PUFA's (Akiba *et al.,* 1995).

Feeding birds with PUFA also resulted in reduction of serum cholesterol and very low density lipoproteins which are highly correlated with abdominal fat deposition (Crespo and Esteve-Garcia, 2001 and 2003) compared to MUFA and SFA. Lipid unsaturation is negatively associated with impaired carcass and meat firmness thus easily susceptible to lipid oxidation subsequently resulting in oily meat. The structure of fatty acid present in triglycerides determines the melting point of depot fat which is presented in Table 1.

When the ratio of unsaturated to saturated fatty acid (UFA: SFA) is too high then the carcass is more prone to lipid oxidation and upon cooking it may result in

Table 1: Melting point of some fatty acids

Saturated fatty acids		Unsaturated fatty acid	
Fatty acid	Melting point	Fatty acid	Melting point
Lauric acid (12:0)	44^{o}c	Palmitoleic acid (16:1ω7)	0^{o}c
Myristic acid (14:0)	54^{o}c	Oleic acid (18:1 ω9)	13^{o}c
Palmitic acid (16:0)	63^{o}c	Linoleic acid (18:2 ω6)	-5^{o}c
Stearic acid (18:0)	70^{o}c	Linolenic acid (18:3 ω3)	-11^{o}c
Arachidic acid (20:0)	76^{o}c	Arachidonic acid (20:4 ω6)	-49^{o}c

(Adopted from Nelson and Cox, 2000)

warmed-off flavor, and also the water holding capacity of meat decreases. Especially n-3 PUFA due to their double bonds, are highly sensitive to oxidative deterioration and are responsible for the formation of peroxides and off-flavors and taste deterioration (Eriksson, 1987).

In the birds fed with UFA, the natural antioxidants present in birds were depleted, to nullify the lipoperoxides released during the metabolism. Thus their deposition in the carcass is interfered which ultimately resulted in decreased shelf life of carcass. Enriching poultry meat with MUFA had similar effect on oxidative stability as that of saturated fats.

According to Kavouridou *et al.,,* (2008) and Crespo *et al.,,* (2002b) fat source did not have significant ($P>0.05$) effect on carcass nitrogen gain but they found, animals fed with more saturated diets had higher intake and excretion of nitrogen compared to animals fed with unsaturated oil, resulting in lower nitrogen efficiency.

2.4 Role of carcass fat in human nutrition vis a vis demand of lean meat

The consumption of saturated fats caused an unwanted increase in cholesterol concentration in plasma, associated with development of coronary heart disease in humans. Also if daily intake of n-6 fatty acids was greater in relation to n-3 fatty acids (such as breast meat of chicken which contains n-6: n-3 ratio as 30) many results in pathological changes in human like atherosclerosis, thrombosis, rheumatic arthritis, bronchial asthma, diabetic mellitus, disturbed developments in brain, so on (Farrell, 1995), most particularly due to oxidation of low density lipoprotein cholesterol as stated by Dwyer (1995). Therefore, human nutritionists recommend that not more than 30% of dietary energy should come from fat. The relation between saturated, monounsaturated and polyunsaturated fatty acids should be equal to 1:1:1 and that of n-6: n-3 less than 5:1.

2.5 Role of L-Carnitine in poultry nutrition

L-carnitine (ß-OH-γ-N-trimethylaminobutyric acid) is a small molecular weight, water soluble quaternary amine which occurs naturally in micro-organisms, plants and animals (Bremer, 1983). It promotes mitochondrial β-oxidation of long chain fatty acids by facilitating their transfer across the inner mitochondrial membrane, there by facilitating fatty acid oxidation and reducing the long-chain fatty acids availability for storage in adipose tissues. Halvorsen *et al.*, (2001) found that the peroxisomal β-oxidation was known to be stimulated, by higher concentration of MUFA and higher dietary fat, but they do not yield ATP. Thus energy efficiency by this mechanism is poorer and also increases serum triglycerides with subsequent increase in abdominal fat deposition. Rather L-car stimulates mitochondrial β-oxidation of fatty acids by facilitating their transport across the mitochondrial cell membrane

β-oxidation of long chain fatty acids is brought about by carnitine in four steps (Feller, 1988); formation of a long-chain acyl-CoA ester by the CoA synthetase located outside the mitochondria; formation of a long-chain fatty acylcarnitine ester at the outer face of the inner mitochondrial membrane by the enzyme carnitine palmitoyltransferase A (CPT A); transport of the carnitine ester to the inside of the membrane; and regeneration within the mitochondria by CPT B of the long-chain fatty acyl-CoA and free carnitine (fig: 1).

The increased oxidation of fatty acid by L-carnitine (L-car) may result in decreased availability of long chain fatty acids for esterification to triacylglycerols, at the same time increasing the acetyl-CoA. This acetyl-CoA can be effectively utilized for the pyruvate carboxylation which can supply C-Chain for amino acid

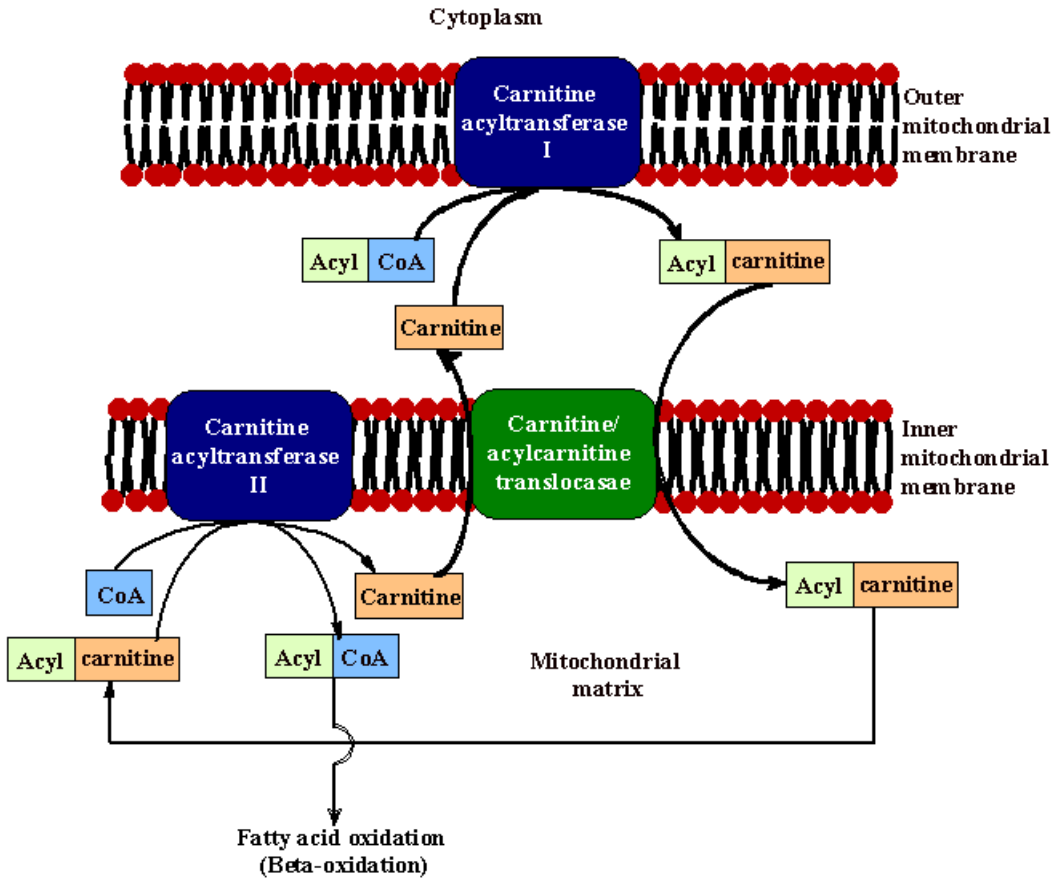

Figure 1: β-oxidation in mitochondrial membrane facilitated by L-Carnitine.

synthesis (Rabie and Szilágyi, 1998). This may attribute to increased utilization of dietary nitrogen.

Secondary function of carnitine is being a radical scavenger; action is brought by buffering and removing the potentially toxic accumulation of aceyl-CoA compound of either exogenous or endogenous origin by trapping acyl group as carnitine esters thus protecting cell membranes from cholesterol oxidation or lipoperoxidation. It also facilitates the removal of short-chain and medium-chain fatty acids from mitochondria that accumulates as a result of normal and abnormal metabolism (Bremer, 1983, Rebouche, 1992), as well as enhances the utilization of pyruvate and the oxidative phosphorylation; together these functions facilitate cellular energy production.

Other functions L-car is reduction of adiposity of broiler chicken. Xu *et al.,* (2003) reported supplementation of L-car 50, 75 or 100 mg/kg decreased the total activity of lipoprotein lipase (LPL) enzyme which catalyzes the conversion of triglycerides to glycerol and fatty acids. LPL increases hydrolysis of very low density lipoprotein, which is suggested to play major role in regulating the deposition of fat in the animal body thus minimizes the deposition of fat in subcutaneous tissue. Thus L-car was considered, as hypolipidemic drug in rabbits (Diaz 2000).

Several studies on pigs, fish, quail, foals, and broiler chickens have shown that growth performance was significantly improved by feeding dietary L-car (Schuhmacher *et al.,* 1993; and Rabie *et al.,* 1997). Supplementing L-car in broiler diets may contribute to a reduction in the degree of adiposity in the broiler chicken, particularly when they are fed on diets with different energy contents. Thus, if L-car was added it could enhance the utilization of dietary fat and the other dietary components would be metabolized in favor of protein accretion (Rabie and

Szilagyi, 1998). In young rats (Susanna Iossa, 2002) the amount of metabolizable energy intake stored as lipid was lower at acetyl-L-carnitine. Whereas, the percentage of ME intake stored as protein was greater in acetyl-L-carnitine treated old rats.

2.6 Biosynthesis of L-carnitine

L-carnitine synthesized endogenously from methionine and lysine (José Henry Osorio, 2006). During the synthesis, L-lysine provides the carbon chain and nitrogen atom of carnitine, and L-methionine provides the methyl groups. The conversion of tri-methyl-lysine to carnitine requires two hydroxylations catalysed by two specific monooxygenases that use α ketoglutarate as an electron donor to activate dioxygen. The α-amino acids are cleared into carbon dioxide and succinate. Both the enzymes require Fe (II) and are activated by ascorbate (Fig: 2). Endogenous biosynthesis may be sufficient to cover normal requirements in all mammals and bird species, when precursors and cofactors of the L-car are sufficient in the diet (Arslan, 2006). Lysine and methionine are two limiting amino acids of poultry. When these two amino acids are not provided in diet, then there may be deficiency of carnitine as the diets of poultry are mainly composed of maize and soy bean (5 and 12 mg/kg respectively).

Daily recommended L-carnitine dosage are for laying hen, breeder hen, broilers 50 mg/kg; turkeys 60 mg/kg; pigeons 25mg/ kg and breeding pigeon 80mg/kg.

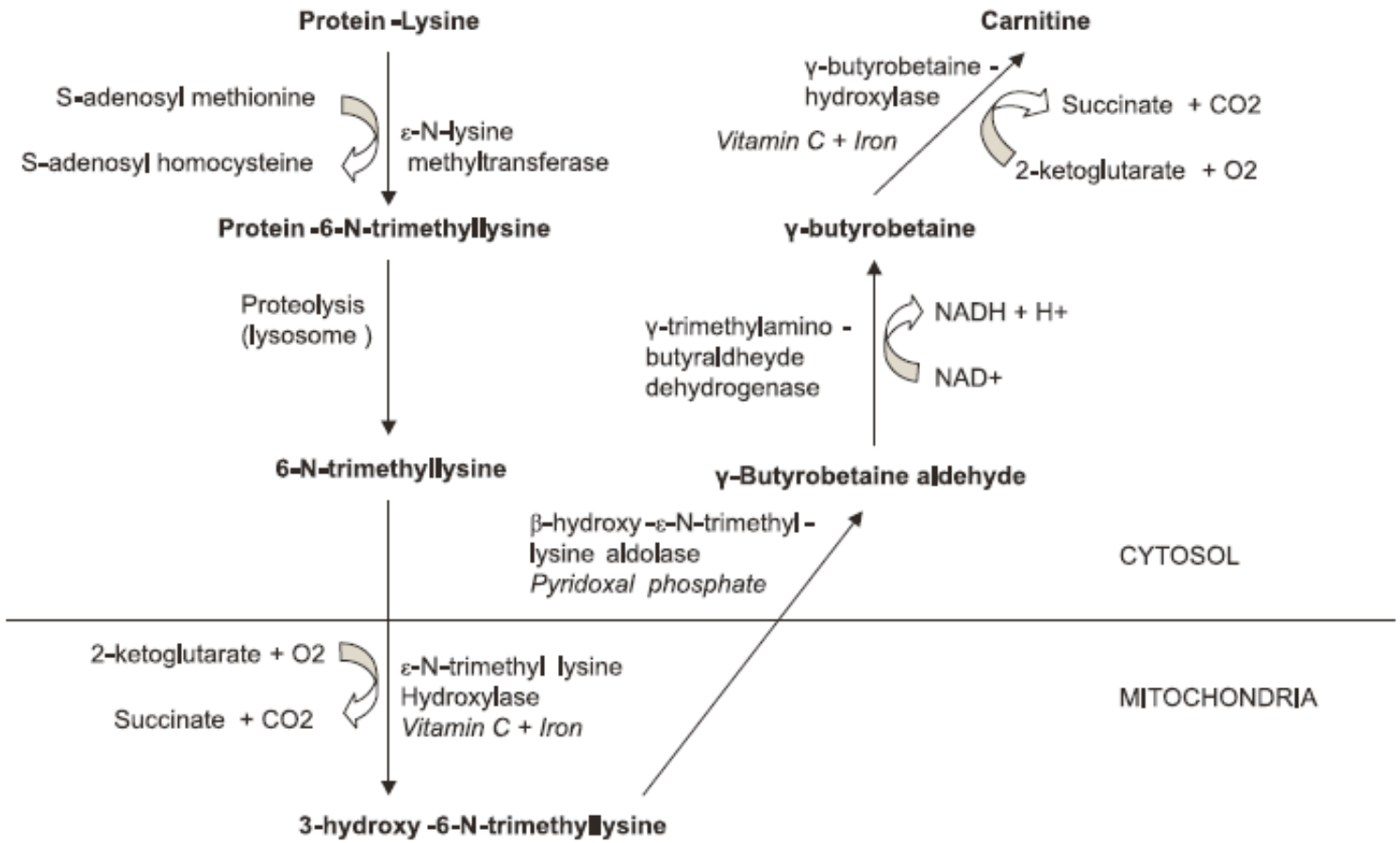

Fig: 2 Biosynthesis of Carnitine (José Henry Osorio, 2006)

2.7 PERFORMANCE PARAMETERS

The effects of dietary fat supplements and L-carnitine on the weight gain, feed consumption, feed conversion ratio, carcass yield, moisture percentage of liver, light and dark muscles, percentage of fat in the abdominal region, liver, light and dark muscles, and serum lipid profiles as reported by different authors are mentioned below:

2.7.1 Body weight gain

The weight gain of broilers was significantly high with diets fed on oil when compared to diets without oil and also depends upon the level of fat inclusion. Nitsan *et al.,* (1997) found that addition of 3% soybean oil (SBO) in broilers diet improved weight gain than diet containing without oil. Study conducted by Paichok Panja (1996) with different levels of saturated fats (palm oil), the weight gain was significantly ($P<0.05$) higher with diet containing 4, 6 and 8% level of palm oil inclusion when compared to 2% palm oil and basal diet without oil (Table 2).

Nyebpor *et al.,* (2007) reported feeding broilers with isocaloric diet (2925 kcal/kg ME) with different levels of soybean oil (2, 4 and 6%) there is significant ($P<0.05$) increase in body weight gain during starter period (7-21 days) and over all period (7-42 days) as the level of oil is increased. The weight gain during starter period was 564.5g, 586g, 595g and finisher period was 2094g, 2187g, 2203g at 2, 4 and 6% level of SBO respectively. But level of oil inclusion didn't have any significant ($P>0.05$) effect on weight of broilers during finisher period (1530g, 1566g, and 1549g). Similarly Jayalakshmi *et al.,* (2006) found that there was no significant ($P>0.05$) difference in weight gain when broilers fed with different

levels of sunflower acid oil (0, 2, 3 and 4%). Similarly, other authors (Crespo and Esteve-Garcia, 2002a; Sanz *et al.,* 1999) reported, that the levels of fat inclusion (10 or 8%) and sources of fat (tallow, lard, sunflower oil and linseed oil) did not have any significant (P>0.05) effect on body weight.

Tabeidian *et al.,* (2005) reported feeding chick with different levels of SBO (0, 2.5, 5, 7.5) with NRC recommended protein level had no significant (P>0.05) effect on weight gain in 7-21 and 21-42 day old chicks, however at 42-49 days, there was significant (P<0.05) reduction of weight gain at 7.5% of SBO inclusion.

The weight gains in broiler do not depend upon the saturation of fats. Several experiments indicated that dietary fat source has no significant (P<0.05) effect on the productive performance, as long as the ratio of energy to protein, to amino acids and or other nutrients are balanced (Sibbald, 1962). Similarly, Sanz *et al.,* (1999) reported that there was no significant (P>0.05) effect of fat source (tallow, lard, sunflower oil) on body weight gain, feed intake, FCR. However, significant (P<0.05) effect on body weight gain was observed at low, medium and high energy concentration of diets enriched with sunflower oil (2907, 3026 and 3074 kcal/kg ME) and animal fat blends (2883, 2979 and 3050 kcal/kg ME).

Coetzee and Hoffman (2002) also reported that there was no significant (P>0.05) difference in body weight gain when six different combinations of monounsaturated fats and saturated fats using canola oil (CAO) and famarol oil (FAO) viz. 100% FAO, 80% FAO-20%CAO, 60%FAO-40%CAO, 40% FAO-60%CAO, 20%FAO-80%CAO and 100% CAO, as all the blends were balanced with energy to protein ratio. Similarly Sanz *et al.,* (2000b) reported weight gain was not significantly (P>0.05) influenced when polyunsaturated fats were replaced

with saturated fats (sunflower oil enriched diet, sunflower + 8% Tallow, sunflower + 12% tallow and tallow) during 21 to 49 days of age, the weight gains were 2046.1, 2087.8, 2030.1 and 2006.8g respectively.

Scaife *et al.,* (1994) reported that there was significant ($P<0.05$) improvement in body weight gain in broilers fed with diets containing beef tallow and soybean oil when compared to other blends of rape seed oil and marine oil (Table 2).

Wongsuthavas *et al.,* (2007a) reported feeding broiler with five different ratios of SFA:UFA (1:1, 1:2, 1:3, 1:4, 1:5) with 3 levels of fat (3, 6 and 9%) found there was no clear trend of ratio of fatty acid affecting average daily gain even though there is significant increase in daily weight gain at 3 and 6% fat inclusion. At 3% and 6% level of inclusion highest weight gain was seen at 1:5 SFA:UFA ratio when compared to other ratios of SFA:UFA.

Navidshad *et al.* (2006) reported that feeding diets with UFA: SFA ratio 6.5 adversely affected weight gain (56.13 g/d) when compared to other ratios of UFA: SFA 2, 3.5 and 5 (59.61, 60.66 and 60.43 g/d, respectively) during 10-28days of age whereas during 29-42 days of age, the weight gain did not differ significantly between the ratios.

Xu *et al.,* (2003) reported supplementing L-car either at 0, 50, 75 and 100 mg/kg diet found there was no significant ($p<0.05$) difference in weight gain but there was increase in weight gain when compared to 0 level of L-car.

Lien and Horng (2001) reported supplementing 160 mg/kg L-car to diets don't significantly ($P>0.05$) influence the growth performance of broiler chicken. Similarly Leibetseder (1995) recorded that body weight gain is unaffected by dietary carnitine either in L or DL form at 200 mg/kg diet.

Others also found that there was no significant (P>0.05) difference in overall performance of broiler (Daskiran and Teeter 2001 and Cartwright 1986). Japanese quail (Sarica *et al.,* 2005 and 2007) and turkey fed with L-car (Barker and sell 1994).

Rabie *et al.,* (1997) indicated there was significant (P<0.05) increase in body weight gain by graded levels of L-car (50, 100 and 150 mg/kg) supplementation during first and second weeks of experiment. He concluded the effectiveness of L-car on improving body weight gain and decreasing fat deposition in broilers may depend on age at which L-car is added.

Rabie and Szilágyi (1998) reported supplementing L-car at 0 and 50 mg/kg diet with iso-nitrogenous (18%) diet containing three levels of metabolizable energy (3217, 3050 and 2907 kcal/kg) for a period of 18 to 53 days, found there was significant (P<0.05) increase in body weight gain during 18-25 and 25-32 day and overall experiment period (18-53 days).

Haghighi Khoshkhoo *et al.,* (2006) reported supplementing L-car (0 and 375 mg/kg), significantly (P<0.05) increased body weight gain during 6^{th} and 7^{th} week of age. He concluded that L-car can improve body weight at the end of rearing period, mainly because of higher metabolic activity and high energy demand of chicken, which was obvious at high levels (375mg/kg) of L-car supplementation than lower levels (125, 250mg/kg).

2.7.2 Feed consumption

Paichok Panja (1996) found there was no significant (P>0.05) difference in feed intake by feeding broiler with saturated fats (8%, palm oil) and no added dietary fat (97.86g vs 95g).

Balevi and Coskun (2000) reported lowest feed consumption was recorded for fish oil fed groups than tallow fed groups (78.03g/day vs 93.3g/day). He explained high intake of feed in tallow fed groups, because of lower energy levels. Similarly, Azman *et al.,* (2005) reported significantly (P>0.05) highest feed intake was recorded at tallow fed groups compared to poultry grease and SBO fed groups.

Nyebpor *et al.,* (2007) reported that feed intake of birds fed diet supplemented with 4 and 6% were significantly (P<0.05) higher (3960g and 3940g respectively) than birds fed diet containing 2% oil (3882g). Higher feed consumption resulted in heavier body weight for 4 and 6% level of inclusion.

Wongsuthavas *et al.,* (2007a) reported that when broilers were fed with lowest ratio of SFA: UFA (1:5) there was no significant reduction in average daily feed intake (Table 2).

Newman *et al.,* (2002) reported that there was no significant (P>0.05) effect on feed intake when broiler fed 80g/kg tallow, fish oil and sunflower oil. Whose ratio of SFA: MUFA: PUFA were 31:40:26, 13:23:64 and 28:25:43 respectively, but chicks fed tallow diet tend to consume more feed (5531 g/bird) then sunflower oil gfv(5225g/bird), fish oil (5212 g/bird).

Crespo and Esteve-Garcia (2001) reported the fat source (tallow, olive oil, sunflower oil and linseed oil) did not have significant (P>0.05) effect on feed intake during finisher period (21 to 42 days). However, feed intake decreased significantly (P<0.05) as the dietary fat level increased from 6 to 10%.

Rabie *et al.,* (1998) reported addition of L-car to grower-finisher diets of broilers resulted in significantly (P<0.05) increased feed consumption.

Rezaei *et al.,* (2007) reported that feed intake was significantly (P<0.05) increased by increasing the level of SBO (1, 3 and 5%), where as feed intake was

Table 2: Effect of added dietary fat source and L-carnitine on performance parameters

Source	Age	Type of fat	Inclusion level	WG/bird (g)	FI/bird (g)	FCR
Scaife *et al.*, 1994	19-56 days	Tallow	50g/kg	1874	4577	2.44
		Soya	50g/kg	1863	4357	2.34
		Tallow+Soy(0.5:0.5w/w)	50g/kg	1888	4467	2.37
				ADG	ADFI	
Zollitsch *et al.*, 1996	21 -41 days	Soybean oil	6%	72.1	119.8	1.67
		Poultry grease		72.1	113.5	1.58
		Beef tallow		74.4	133.3	1.80
Sanz *et al.*, 1999	21-49 days	Tallow + Lard	50:50 (w/w)	77.8	150.07	1.95
		Sunflower oil		78.57	148.06	1.9
Sanz *et al.*, 2002	21-52 days	Tallow	80g/kg	2407	5281	2.2
		Lard	80g/kg	2434	5342	2.2
		Sunflower oil	80g/kg	2318	5224	2.24
Newman *et al.*, 2002	3 -5 weeks	Fish oil	80g/kg	2714	5212	1.92
		Sunflower oil	80g/kg	2808	5225	1.87
		Tallow	80g/kg	2712	5531	2.05
Wongsuthavas *et al.*, 2007	42 days	(3% fat inclusion)	SFA:USFA	ADG	ADFI	
		Tallow + soybean oil	1:1	36.3	94.4	2.6
			1:2	35.7	95.4	2.67
			1:3	38.7	95.8	2.48
			1:4	40.1	94.4	2.37
			1:5	42.3	98.7	2.34
Paichok panja. 1996	49 days	Palm oil	0%	2152.6	4655	2.16
			2%	2134.9	4689.8	2.21
			4%	2257.4	4742.7	2.1
			6%	2257.4	4602.6	2.05
			8%	2362.3	4795.1	2.04
Rabie *et al.*, 1998	18-53 days	L-car	0 mg/kg	1760	4190	2.39
			50	1841	4218	2.3
Xu *et al.*, 2003	1-49 days	Corn oil 5%		ADG	ADFI	
		L-car	0 mg/kg	49.42	108.12	2.49
			25	50.11	108.37	2.43
			75	50.18	109.73	2.37
			100	50.14	109.14	2.35
Rezaei *et al.*, 2007	42	L-car	0mg/kg	1962	3606.8	1.83
			250mg/kg	1964	3604.7	1.83

ADG: average daily gain; ADFI: average daily feed intake

not significantly (P>0.05) influenced by the dietary L-car supplementation. He also indicated that there was no significant (P>0.05) interaction between level of fat and L-car.

2.7.3 Feed to gain ratio

The feed conversion can be improved by increasing the level of fat source. Nyebpor (2007) reported that feed conversion ratio improved significantly (p<0.05) with the increasing levels of SBO in broiler diets during starter phase. Significant difference in FCR was found at 0 and 6% level of inclusion, but not between 4 and 6% level of inclusion (1.81 and 1.78 respectively). And the level of SBO did not have significant (P>0.05) effect on feed efficacy during finisher period.

Balevi and Coskun (2000) reported feeding broiler with different fat source significantly (P<0.05) effected the feed conversion ratio. Lowest ratio was obtained for corn oil diet (1.95), flaxseed oil diet (1.99) and highest for tallow diet (2.26), whereas FCR was almost same for sunflower oil, olive oil and fish oil (2.08) and for soybean oil it is 2.04, while lowest weight gains were obtained to fish oil diets (37.53g/day) and highest for corn oil group (43.85g/day).

Newman *et al.*, (2002) reported feed to gain was significantly (P<0.05) better for sunflower oil fed group (1.87) when compared to fish oil (1.92) and tallow (2.05).

Wongsuthavas *et al.*, (2007a) reported that at each level of fat (3, 6 and 9%), the highest intake of unsaturated fats was associated with lowest FCR but the feed intake was not low and he concluded that low FCR for birds fed with high UFA is related with high digestibility and or to higher protein: fat ratio of carcass and or to less heat production.

Crespo and Esteve-Garcia (2001) reported feed efficiency was significantly ($P<0.05$) better in birds fed 10% of fat because of higher metabolizable energy when compared to 6% fat. In male broilers feed efficiency was better by feeding linseed oil and sunflower oil diet than tallow and olive oil, while in case of female olive oil had better feed efficiency than tallow fed birds.

Azman *et al.,* (2005) indicated that significantly ($P<0.05$) better FCR for broilers fed on monounsaturated fats (1.58) than polyunsaturated (1.67) fats or saturated fats (1.80) during 21 to 41 days of age (poultry grease vs soybean oil vs tallow respectively), in contrary to the finding of Zollitsch *et al.,* (1996), who reported better FCR in broilers fed with PUFA rather, than SFA or MUFA.

Xu *et al.,* (2003) noticed there was no significant ($P>0.05$) effect of L-car on performance parameters. Similarly, Rezaei *et al.,* (2007) reported that feeding broilers with L-car alone or in combination with different levels of oils did not show any significant ($P>0.05$) effect on body weight gain, feed intake and FCR. Whereas Rabie *et al.,* (1998) found FCR was more efficient for diets supplemented with 50mg/kg L-car than diet without L-car supplementation.

Performance parameters reported by various workers was listed in Table 2.

2.8 CARCASS PARAMETERS

2.8.1 Dressing percentage

Variation in source of supplemental fats (tallow, olive oil, sunflower oil, soybean oil, chicken oil, linseed oil and sunflower acid oil) did not influence the carcass yields and dressing percentages (Crespo and Esteve-Garcia (2001); Rondelli *et al.,* (2004); Jayalakshmi *et al.,* 2006). Similarly Sanz *et al.,* (1999) reported dressing percentage was unaffected neither with fat source (i.e., animal fat

blend and sunflower oil) nor with energy levels (low, medium and high energy levels).

Wu *et al.,* (1994) reported that in male broilers, there was significant (P<0.01) increase in body weight gain, dressing percentage, and thigh yield (P<0.05) as the ratio of UFA: SFA increased from 2.0 to 6.0.

Study conducted by Sarica *et al.,* (2007) in quail found sources of fat (sunflower and fish oil) had significant effect on cold carcass yield (64.1 and 62.8% respectively) and there was no significant (P>0.05) interaction between fat source and L-car. Studies conducted in broiler chicken and quails by earlier workers reported supplementing L-car did not improve dressing percentage of carcass (Daskiran and Teeter 2001; Rabie *et al.,* 1998 and Sarica *et al.,* 2005)

2.8.2 Giblets weight

Wongsuthavas *et al.,* (2007) reported dietary fat source (tallow, soybean oil and krabok oil) significantly (P<0.05) effected the liver weight (2.84, 3.22 and 2.38g respectively) but not other organ weights. Rezaei *et al.,* (2007) also found, the level of fat inclusion significantly (P<0.05) increased the percentage of liver weight but not heart.

Rabie *et al.,* (1998) and Sarica *et al.,* (2005 and 2007) reported the weights of giblet, liver, gizzard and heart were not significantly (P>0.05) influenced by L-car supplementation in broiler and Japanese quails respectively.

2.8.3 Abdominal fat:

Rondelli *et al.,* (2004) reported that feeding broiler with three different fat sources (soybean oil, chicken oil or bovine fat) did not show significant (p>0.05)

difference in abdominal fat percentage. Nyebpor *et al.,* (2007) reported level of oil did not show any significant (P>0.05) effect on abdominal fat contnet. The abdominal fat pad percentages were 3.38, 3.5 and 3.73% at 2, 4 and 6% level of SBO.

Valencia *et al.,* (1993) noticed that dressing percentage and quantity of abdominal fat were not influenced by source of oil but fatty acid content of adipose tissue was altered by source of oil.

Taher Rabbie (2005) reported increasing the dietary oil and fat levels decreases abdominal fat percentage although analysis of variance showed the effect was insignificant. At 4% inclusion of sunflower oil, duna fat and keim fat the percentage of abdominal fat was 1.58, 1.10 and 1.60% respectively. In keim fat the abdominal fat content was more than other fats, because keim fat is rich source of SFA.

Deaton *et al.,* (1981) noticed that, with increase the dietary animal fat (TAL) concentration, the abdominal fat deposition was significantly (P<0.05) increased, while Keren-Zvi *et al.,* (1990) reported a significant (P<0.05) reduction in abdominal fat pad weight by increasing the concentration of dietary vegetable oils at the same energy density.

Sanz *et al.,* (1999) reported that broiler fed on diets containing animal fat blends or tallow had greater abdominal fat pad weights (80.51g and 114.51g respectively) than birds fed with sunflower oil enriched diets (62.58g). Similarly there was linear increase in the abdominal fat pad deposition, when animals fed with increasing tallow enriched diets few days before slaughter (Sanz *et al.,* 2000b).

Sanz *et al.,* (2000a) reported that abdominal fat deposition of chicken fed with sunflower enriched diets was significantly lower than tallow enriched diets

(2.63 ± 0.47 vs 3.03 ± 0.44 g/100g live weight; P<0.05). Several factors may be involved in the variation of fat deposition with degree of saturation of dietary fatty acids. These may include different signals for feedback regulation of endogenous synthesis or differential tissue uptake or metabolism of fatty acids. Shimomura *et al.,* (1990) reported a higher postprandial lipoprotein lipase (LPL) activity in heart and soleus muscle of rats fed on safflower oil- enriched diet than in rats fed on a tallow enriched diet, suggesting different uptake by tissues.

Crespo and Esteve-Garcia (2002a and 2002b), found there was significant difference (P<0.05) in abdominal fat pad weight by feeding broiler with four different fat sources (tallow, olive oil, sunflower oil, linseed oil), Table 3. Birds fed with sunflower and linseed oil had less abdominal fat deposition than those fed tallow or olive oil, but the basal diet without oil showed significantly (P<0.05) lower values than oil supplemented diets. Thus it can be concluded that the difference in fat deposition of broilers fed with different fatty acid profile, was more related to different rates of lipid oxidation rather than lipid synthesis. The same trend was seen in the experiment conducted by Crespo and Esteve-Garcia (2001).

Newman *et al.,* (2002) found significantly (p<0.01) lower abdominal fat pad mass in broiler fed with sunflower and fish oil at 8% inclusion compared to tallow fed broilers. Sanz *et al.,* (2000a) reported that feeding broilers with unsaturated fats found significant (P<0.05) reduction in abdominal fat pad percentage than saturated fats.

Wongsuthavas *et al.,* (2007a) noticed the abdominal fat percentage was reduced significantly (P<0.05) with decreasing SFA: UFA ratio. The same pattern was seen for the absolute weight of the abdominal fat (36.7, 34.0, 36.9, 28.5 and

28.3g for 1:1, 1:2, 1:3, 1:4 and 1:5 ratio of SFA:UFA respectively) but did not differ statistically. The percentage of abdominal fat was shown to be significantly ($P<0.05$) lower for the diets containing 3% and 6% added fat (1.79% and 1.92%) than for the diets containing 9% fat (2.49%). He opined that higher abdominal fat deposition was due to high energy density of the diets at 9% fat inclusion.

Wongsuthavas *et al.,* (2007b) reported the amount of abdominal fat was significantly reduced ($p<0.05$) when about 75% of tallow was replaced by soybean oil, and reduction of abdominal fat was in order of 20-30%.

Nosrati *et al.,* (2006) found feeding broiler with UFA: SFA ratios (2, 3.5, 5 and 6.5) significantly ($p<0.05$) reduced abdominal fat percentage at 28 day of age (1.4, 1.3, 1.1 and 1.7%) compared to 42 day of age (1.51, 1.94, 1.92 and 2.76%). They also reported birds fed with the most unsaturated fats (UFA: SFA, 6.5) at 28 and 42 day of age had significantly ($p<0.05$) higher abdominal fat pad percentage (1.7 and 2.76% respectively) than other treatment groups.

Xu *et al.,* (2003) reported abdominal fat percentage was significantly ($P<0.05$) reduced at all the levels of L-car (25, 50 75 and 100 mg/kg) supplementation. Similarly, Rabie *et al.,* (1998) reported that there was significant ($P<0.05$) reduction in abdominal fat pad percentage by supplementing 50 mg/kg L-car. Perhaps, there was lack of such response, in reduction of abdominal fat content with graded levels of carnitine (50, 100 and 150 mg/kg) supplementation, to broiler diets (Rabie *et al.,* 1997). These findings were controversy to the findings of Daskiran and Teeter (2001), who found there was no significant ($P\geq0.1$) effect of L-car on abdominal fat pad weight. The abdominal fat pad weights were 28.09, 28.14, 27.22, 26.89, 26.14 and 28.03g, for 0, 40, 80, 120, 160 and 200ppm, of L-car supplementation.

Rezaei *et al.,* (2007) reported that feeding broilers with 3% soy oil significantly ($p<0.05$) lowered the abdominal fat deposition when compared with 1% and 5% of oil inclusion (1.74 and 1.80% respectively). Addition of L-car to diets (0 and 250mg/kg) tend to have a significant ($p<0.07$) effect in lowering abdominal fat content (1.32 vs 1.57%). There was significant ($P<0.05$) interaction between levels of oil and L-Car supplementation.

Arslan *et al.,* (2004) noticed that the supplementation of L-Car (100 mg/kg) apart from reducing abdominal fat percentage (2.41% vs 3.47%), it also significantly ($P<0.05$) increased SFA concentration without modifying MUFA concentration in abdominal fat of geese. Table 3 represents the abdominal fat percentage, of various authors.

2.8.4 Breast yield:

Newman *et al.,* (2002) reported the feeding broiler with 1.57, 4.87 and 0.84 PUFA: SFA ratios (fish oil, sunflower oil and tallow diets respectively) were resulted in lager breast muscle yield. The ratio of breast muscle: fat pad was significantly ($P<0.05$) greater for higher ratio of PUFA: SFA. The water content of breast muscle was significantly higher for the fish oil and sunflower oil diets than those fed with tallow diet.

In case of female broilers, Crespo and Esteve-Garcia (2001) observed the level of fat inclusion and type of fat had no significant ($P>0.05$) effect on yields of light and dark muscles. Similar findings were reported by Rondelli *et al.,* (2004) by feeding soybean oil, chicken oil or bovine fat (15.3, 15.0 and 14.9%respectively) and Sanz *et al.,* (1999) by feeding tallow, lard and sunflower oil (488.89, 498.46 and 481.04g respectively).

Table 3: Effect of added dietary fat sources and L-carnitine on percentage of abdominal fat pad in broiler chicken:

Source	Age (days)	Type of fat	Inclusion level	AFP%
Sanz *et al.,* 1999	52	Tallow	8%	3.46
		Sunflower		2.97
Sanz *et al.,* 2000a			UFA: SFA	
		Tallow	2.53	3.03
		Sunflower oil	6.16	2.63
Crespo *et al.,* 2001	42	Tallow	6-10%	2
		Olive oil		2.07
		Sunflower oil		1.7
		Linseed oil		1.75
Crespo and Esteve-Garcia ., 2002(a)	48	Basal	Without oil	1.35
		Tallow	10%	2.09
		Olive oil		1.89
		Sunflower oil		1.77
		Linseed oil		1.64
Newman *et al.,* 2002	35	Tallow	8%	3.96
		Sunflower oil		1.5
		Fish oil		1.67
Rondelli *et al.,* 2004	50	Control	No fat	2.3
		Soybean oil	3%	2.1
		Chicken oil		2.2
		Bovine fat		2.2
Wongsuthavas *et al.,* 2007		Blend of tallow and soy oil (3%)	SFA:UFA	
			1:1	2.76
			1:2	2.47
			1:3	2.44
			1:4	1.82
			1:5	1.79
Rabie *et al.,* 1998	53	L-car	0 mg/kg	2.62
			50 mg/kg	2.11
Xu *et al.,* 2003	49	Corn oil 5%	0mg/kg	1.17
		L-car	25mg/kg	1.11
			50mg/kg	0.98
			75mg/kg	1
			100mg/kg	1.03
Rezaei *et al.,* 2007	42	Soy oil	1%	1.94
			3%	0.91
			5%	1.86
		Soy oil + L-car (250mg/kg)	1%	1.52
			3%	0.68
			5%	1.75

Rezaei *et al.,* (2007) reported the levels of fat inclusion significantly (P<0.05) influenced the breast meat yield. The breast yield percentage was significantly high for 3% level of SBO (17.54%) than for 1 or 5% level of SBO (14.92 and 16.96% respectively). Supplementing L-car had no significant (P>0.05) effect on breast meat yield (16.14 and 16.81% for 0 and 250 mg/Kg).

Xu *et al.,* (2003) reported breast muscle yield increased significantly (p<0.05) by supplementing with 50 or 75 mg/kg L-car and Rabie *et al.,*1998 also reported that breast yield significantly increased by supplementing 50 mg/kg L-car. Whereas few authors (Daskiran and Teeter, 2001; Rezaei *et al.,* 2007 and Arslan *et al.,* 2004) reported that there was no significant (P>0.05) effect of L-car supplementation on breast meat yield. Table 4; represent breast yield percentage as reported by various authors.

2.8.5 Fat content of light and dark muscle and liver

Newman *et al.,* (2002) found fat content of light muscle was greater for tallow fed chickens (0.88%) than those fed either fish oil or sunflower oil (0.63% and 0.7% respectively)

Crespo and Esteve-Garcia (2001) found the fat and protein content of light and dark muscle were unaffected (P>0.05) by the dietary fat type. However the lipid content of dark muscle was more than light muscle (Table 5).

Scaife *et al.,* (1994) observed the muscle fat increased when PUFA were fed than tallow, whereas reverse trend was found in abdominal fat deposition which suggested that dietary PUFA could cause a different distribution of fat in tissues when compared with SFA or monounsaturated fatty acids.

Özdoğan and Akşit (2003) reported that crude fat content of dark and light muscle significantly (P<0.05) differed with fat sources. The fat percentage of both

Table 4: Effect of added dietary fat sources and L-carnitine on breast yield

Source	Type of fat	Inclusion Level	Breast yield (%)
Rondelli *et al.*, 2004	Soy bean oil	3%	15.3
	Chicken oil		15.0
	Bovine fat		14.9
Sanz *et al.*, 1999*	Tallow	8%	488.89
	Lard		498.46
	Sunflower		481.04
Xu *et al.*, 2003	Corn oil (5%)	0 (mg/Kg)	16.99
	L-car	25	17.06
		50	17.97
		75	17.79
		100	17.27
Newman *et al.*, 2002*	Fish oil	8%	572
	Sunflower oil		585
	Tallow		542
Rabie *et al.*, 1998*	L-car	0 mg/kg	510
		50 mg/kg	538
Rezaei *et al.*, 2007	L-car	0 mg/kg	16.14
		250 mg/kg	16.81
	Soy oil	1%	14.92
		3%	17.54
		5%	16.96

*: breast yield in grams

Table 5: Effect of added dietary fat sources and L-carnitine on fat content of light and dark muscle

Source	Type of fat	Inclusion level	Light muscle fat or lipid%	Dark muscle fat or lipid%
Crespo and Esteve-Garcia 2001	Tallow	10%	1.40	2.06
	Olive oil		1.35	2.1
	Sunflower oil		1.44	2.27
	Linseed oil		1.35	2.24
Sanz *et al.*, 1999*	Tallow	8%	23.52	
	Lard		19.99	
	Sunflower		18.53	
Newman *et al.*, 2002		P:S		
	Fish oil 8%	1.57	0.63	
	Sunflower oil	4.97	0.72	
	Tallow	0.84	0.88	
Özdoğan and Akşit 2003**	Sunflower oil	6%	8.85	13.87
	Corn oil		8.71	11.95
	Soybean oil		7.06	11.17
	Tallow		7.15	11.26
Rezaei *et al.*, 2007	Soy oil	1%	0.58	
		3%	1.64	
		5%	1.59	
	Soy oil +L-car (250 mg/kg)	1%	0.45	
		3%	1.09	
		5%	1.68	

* : fat content in grams per 100 g of tissue
** : fat content of light and dark muscles analyzed along with skin

muscles was highest for diets containing sunflower oil (13.87 and 8.85% respectively) whereas those fed diets soybean oil were lowest (11.17 and 7.06% respectively).

Xu *et al.,* (2003) reported the fat content of breast muscle of male broilers was increased significantly ($p<0.05$) by supplementation of 50 or 75 mg L-car /kg diet. But Rezaei *et al.,* (2007) reported fat content of light muscle significantly reduced by supplementing 250mg of L-Carnitine (1.07 vs 1.27%).

Crespo and Esteve-Garcia (2002c) noticed liver fat percentage was significantly ($p<0.05$) high for tallow and sunflower oil diets (6.97 and 6.27) than linseed oil (4.54%). The fat or lipid percentage of light and dark muscle as reported by various workers was listed in Table 5.

2.8.6 Moisture percentage of liver, light and dark muscle:

Özdoğan and Akşit (2003) reported that the moisture content of thigh muscle along with skin was significantly ($p<0.05$) higher in broilers fed a diet containing SBO (71.73%) compared to sunflower oil, corn oil, TAL (70.22, 71.32 and 71.20% respectively) but breast meat moisture content was not affected.

Newman *et al.,* (2002) found the water content of light muscle was more for the fish and sunflower oil (24.3 and 24.1% respectively) diets than tallow diets (19.1%).

2.9 Serum lipid profile:

2.9.1 Serum or plasma triglycerides and cholesterols:

Shimomura *et al.,* (1990) reported that feeding rats with unsaturated fats resulted in increased LPL activity in heart and skeletal muscle resulting in the elevation of fat oxidation rate and depression of serum triglycerides level.

Experiment conducted by Wongsuthvas *et al.,* (2007b) revealed that the concentration of triglycerols in plasma, measured as an index of *de nova* fatty acid synthesis was significantly ($p<0.05$) reduced when beef tallow was replaced with soybean oil. Thus reduction of triacylglycerols is associated with decrease in deposition of fat in abdominal region. The replacement of tallow with soybean oil produced dose dependent lowering of plasma concentration of triglycerides but don't differ statistically.

Newman *et al.,* (2002) reported that feeding diets containing ratios of PUFA: SFA as 1.57, 4.87 and 0.84 (fish oil, sunflower oil and tallow) there was significant ($p<0.05$) reduction of plasma triacylglycerols concentration but plasma cholesterol concentration did not differ significantly ($P>0.05$).

Özdoğan and Akşit (2003) reported dietary fat source significantly ($p<0.001$) effect the serum cholesterol but did not affect serum triglycerides levels. They observed a negative relationship between cholesterol and triglycerides values in the group fed sunflower oil and corn oil.

Sanz *et al.,* (2000a) reported that plasma triglycerides concentration was significantly greater after ingestion of meal and postprandial values were significantly lower in broilers fed sunflower diet than tallow diet, suggesting greater digestibility of unsaturated fatty acids, leading to greater substrate availability and thus faster β-oxidation of polyunsaturated fatty acids. The finding are in controversy with that of Alparslan and Özdoğan (2006), who found feeding broilers with fish oil there was no significant ($P>0.05$) reduction of serum triglycerides and or serum cholesterol levels compared with broilers, fed without oil.

Nosrati *et al.,* (2006) reported as the unsaturation of the diets increased, there was significant reduction of serum triglycerides and cholesterol concentration at 28 day of age, whereas UFA: SFA ratio did not have significant (P>0.05) effect on serum cholesterol at 42 day of age.

Xu *et al.,* (2003) reported that there was significant reduction of serum triglycerides with supplementing L-car. Rezaei *et al.,* (2007) also reported the concentration of serum triglycerides were affected by increasing dietary fat inclusions, mostly between 3 and 5% levels of soybean oil. Addition of L-car significantly decreased the concentration of serum triglycerides and cholesterol.

Arslan *et al.,* (2004) noticed in geese there was no significant (P>0.05) effect of feeding L-car (100 mg/kg) on serum cholesterol and triglycerides (1.89 vs 1.35 g/l and 0.92 vs 1.22 g/l for control group respectively). Serum lipid profile as reported by various workers was represented in Table 6.

2.10 Chemical composition of dietary supplemental energy source (Soybean oil and Tallow)

Wiseman (1984) reported that the fatty acids are the major components of many complex lipids. The fatty acid can be classified mainly as saturated straight and their unsaturated derivatives. Most vegetable oils contain higher levels of palmitic, oleic and linoleic acids, which represented the major components. The composition of fatty acids in these sources is different according to various factors, such as difference in measuring techniques or natural variations.

Chu and Sheldon (1979) indicated fatty acid present in any type of oil seed may vary with geographic location, soil type, climatic, moisture, temperature, maturity of the seed and agricultural practices. Ching (1994) indicated that the difference in

Table 6: Effect of added dietary fat sources and L-carnitine on serum lipid profile

Source	Type of fat	Inclusion level	Plasma/serum triglyceride	Serum cholesterol
Wongsuthavas *et al.*, (2007b)*	Tallow : soybean oil	2.87 : 0.13	2,751	3,650
		1.45 : 1.56	2,110	3,435
		0.72 : 2.28	2,092	3,356
		0.28 : 2.72	2,106	3,144
		0.00: 3.00	1,985	2,794
Newman *et al.*, 2002**		PUFA:SFA		
	Fish oil	1.57	0.24	2.4
	Sunflower oil	4.87	0,28	2.77
	Tallow	0.84	0.42	2.81
Alparslan and Özdoga 2006****	Basal diet	No added fat	25.67	125.50
	Fish oil	2%	25.17	113.50
		4%	24.00	109.83
Xu *et al.*, 2003***	Corn oil (5%) + L-car	0 mg/Kg	70.04	
		25	68.86	
		50	65.57	
		75	66.39	
		100	67.03	
Özdoğan and Akşit 2003***	Sunflower oil	6%	37.75	94.83
	Corn oil		34.67	121.33
	Soybean oil		35.75	105.42
	Tallow		35.92	97.17
Rezaei *et al.*, 2007***	Soy oil	1%	63.25	147.50
		3%	76	148.5
		5%	61.25	137.25
	Soy oil + L-car (250mg/Kg)	1%	64	109.75
		3%	56.5	139
		5%	53.5	136.5

* : µmol/l

** : mmol/l

*** : mg/dl

**** : mg/ 100 ml

measuring techniques or natural variations.

Chu and Sheldon (1979) indicated fatty acid present in any type of oil seed may vary with geographic location, soil type, climatic, moisture, temperature, maturity of the seed and agricultural practices. Ching (1994) indicated that the difference in fatty acids produced from animal fat may vary with diet, age and environmental conditions. Gunstone (1996) reported oils/fats in crude state probably contain phospholipids as minor components. He also added natural oils and fats contains mainly of triacylglycerols.

The fatty acid composition of SBO and TAL as reported by various workers presented in Table 7 and 8.

Table 7: The fatty acid composition (%)* of soybean oil as reported by few authors.

Fatty acid	**no of carbon atoms**	**Balevi and coskun 2000**	**Mossab *et al.*, 2000**	**Rondelli *et al.*, 2004**	**Waldroup 2005**	**Azman *et al.*, 2005**	**Wongsuthavas *et al.*, 2007**
Caproic	C 10:0	-	-	-	0.07	-	-
Lauric	C 12:0	0.04	-	-	0.07	-	-
Tridecylic	C 13:0	-	-	-	0.02	-	-
Myristic	C 14:0	0.02	0.69	0.1	0.1	-	0.2
Palmitic	C 16:0	11.44	10.32	11.9	11.2	16.44	12.9
Palmitoleic	C 16:1	0.04	-	0.1	0.05	-	0.1
Margaric	C 17:0	-	-	-	0.03	-	-
Stearic	C 18:0	3.43	3.62	4.6	3.85	3.35	4.6
Oleic	C 18:1	21.42	21.88	21.5	20.98	20.26	22.7
Linoleic	C 18:2	54.26	58.16	54.7	55.1	48.57	53.1
Linolenic	C 18:3	7.25	5.33	7.2	8.44	2.85	3.6
Arachidic	C 20:0	0.96	-	-	0.12	-	1.4
Behenic	C 22:0	1.16	-	-		-	-
ΣSFA		17.05	14.63	16.60	15.46	19.79	19.10
ΣUFA		82.97	85.37	83.50	84.57	71.68	79.50
UFA/SFA		4.86	5.84	5.03	5.47	3.62	4.16
ΣMSFA		21.46	21.88	21.60	21.03	20.26	22.80
ΣPUFA		61.51	63.49	61.90	63.54	51.42	56.70

* **:** percentage may not add to 100 as other constituents not listed

Table 8: The fatty acid composition (%)* of Tallow as reported by few authors

Fatty acid	no of carbon atoms	Balevi and coskun 2000	Mossab *et al.*, 2000	Newman *et al.*, 2000	Sanz *et al.*,		Crespo *et al.*		Rondelli *et al.*, 2004	Waldroup 2005	Azman *et al.*, 2005
					2000_a	2002	2001	2002_b			
Caproic	C 10:0	-	-	-	-		-	-	-	0.14	-
Lauric	C 12:0	-	-	-	-		-	-	-	0.10	-
Tridecylic	C 13:0	-	-	-	-		-	-	-	0.10	-
Myristic	C 14:0	2.83	3.76	1.04	-	2.40	2.65	3.28	29.2	3.65	0.68
Myristoleic	C 14:1	-	-	-	-		-	-	-	1.97	-
Pentadecylic	C 15:0	-	-	-	-		-	0.49	-	0.28	-
Palmitic	C 16:0	26.78	29.22	25.24	18.4	24.8	24.22	27.2	-	26.79	22.35
Palmitoleic	C 16:1	3.54	-	1.12	1.9	1.70	2.69	2.66	5.3	7.02	-
	C 16:2	1.21	-	-	-		-	-	-	0.00	-
Margaric	C 17:0	-	-	-	-		-	-	-	0.31	-
Stearic	C 18:0	23.29	27.17	6.06	9.0	16.30	16.45	21.4	12.2	16.49	22.49
Oleic	C 18:1n-9	36.76	38.87	38.03	39.4	33.00	36.72	37.71	36.2	38.59	33.82
	C 18:1n-7	-	-				1.92	1.77	-	-	-
Linoleic	C 18:2n-6	3.57	1.47	25.80	26.3	19.70	10.67	4.23	7.4	3.33	16.06
Linolenic	C 18:3n-3	1.05	-	1.49	1.6	1.90	0.83	0.49	5.3	1.26	2.87
Arachidic	C 20:0	0.85	-	-	-		-	-	-	-	-
Behenic	C 22:0	0.08	-	-	-		-	-	-	-	-
	C 22:4n-6	-	-	-	-		0.30	-	-	-	-
ΣSFA		53.83	60.15	32.34	27.40	43.50	43.32	51.88	41.40	47.86	45.52
ΣUFA		44.92	40.34	66.44	69.20	56.30	53.12	46.86	54.20	52.17	52.75
UFA/SFA		0.83	0.67	2.05	2.53	1.29	1.23	0.90	1.31	1.09	1.16
ΣMUFA		40.30	38.87	39.15	41.30	34.70	41.32	42.14	41.50	47ss.58	33.82
ΣPUFA		5.83	1.47	27.29	27.29	21.60	11.80	4.72	12.70	4.59	18.93

* **:** Percentage may not add to 100 as other constituents not listed.

CHAPTER III

MATERIALS AND METHODS

3.1 Place of work

The experiment was conducted at the Poultry Experimental Station, Department of Poultry Science, College of Veterinary Science, Rajendranagar, Hyderabad.

3.2 Experimental Design

Growth trial was conducted in a Randomized block design, comprising 12 dietary treatments each with eight replicate groups and five birds per replicate with two levels of L-carnitine (0, 100 mg/kg).

3.3 Diets

Twelve isonitrogenous, isocaloric treatment diets were formulated for broiler starter and finisher based on corn-soya (Table 9 and 10) using Eco-mix software. The nutrient content of ingredients was taken as per the NRC 1994. Diets T1 and T2 were control diets with tallow (TAL) and crude soybean oil (CSBO), T3 and T4 were similar to T1 and T2 with inclusion of L-carnitine (L-car), (100 mg/kg diet). T5, T6, T7 and T8 diets were formulated to contain ratio of UFA: SFA fatty acids as 60:40, 65:35, 70:30 and 75:25 respectively. Diets T9, T10, T11 and T12 were formulated to contain same ratio of fatty acids to that of T5 to T8 but with supplementation of L-car at 100mg/Kg diet level.

Table 9: Ingredients composition of starter diet (0-28 days)

Treatment Diets	Ingredients (%)					
	Maize	Soya	Tallow	Crude soy oil	Constants*	L-Carnitine mg/kg diet
T1	53.84	39.15	3.28	-	3.73	-
T2	53.00	40.40	-	2.87	3.73	-
T3	53.84	39.15	3.28	-	3.73	100
T4	53.00	40.40	-	2.87	3.73	100
T5	53.47	39.70	1.84	1.26	3.73	-
T6	53.42	39.80	1.44	1.61	3.73	-
T7	53.27	40.00	1.05	1.95	3.73	-
T8	53.22	40.10	0.67	2.28	3.73	-
T9	53.47	39.70	1.84	1.26	3.73	100
T10	53.42	39.80	1.44	1.61	3.73	100
T11	53.27	40.00	1.05	1.95	3.73	100
T12	53.22	40.10	0.67	2.28	3.73	100

*Constants: Dicalcium phosphate 1.903, Calcite powder 0.752, Common Salt 0.35, DL-Methionine 0.246, Choline Chloride 0.1, AB2D3K 0.015, B-E mix 0.03, vitamin B12 0.02, Trace mineral mixture 0.12, L-Lysine HCl 0.097, Cygro 0.05, Auryomycine 0.05.

Table 10: Ingredients composition of finisher diet (28-42 days)

Treatment Diets	Ingredients (%)					
	Maize	Soya	Tallow	Crude soy oil	Constants*	L-Carnitine mg/kg diet
T1	62.46	29.20	4.60	-	3.74	-
T2	62.06	30.60	-	3.60	3.74	-
T3	62.46	29.20	4.60	-	3.74	100
T4	62.06	30.60	-	3.60	3.74	100
T5	62.40	30.00	2.29	1.57	3.74	-
T6	62.35	30.10	1.80	2.01	3.74	-
T7	62.31	30.20	1.31	2.44	3.74	-
T8	62.24	30.32	0.84	2.86	3.74	-
T9	62.40	30.00	2.29	1.57	3.74	100
T10	62.35	30.10	1.80	2.01	3.74	100
T11	62.31	30.20	1.31	2.44	3.74	100
T12	62.24	30.32	0.84	2.86	3.74	100

*Constants: Dicalcium phosphate 1.797, Calcite powder 0.753, Common Salt 0.35, DL-Methionine 0.226, Choline Chloride 0.1, AB2D3K 0.015, B-E mix 0.03, Vitamin B12 0.02, Trace mineral mixture 0.12, L-Lysine HCl 0.126, Cygro 0.05, Probiolac 0.08 and Liver extract 0.08.

Prior to preparation of treatment diets the fatty acid profile of supplementary fats CSBO and TAL (Table 11) was analyzed after methylesterfication of fatty acid with methanol and concentrated sulphuric acid (98:2 v/v) as per AOCS official method ce2-66 and this fatty acid methyl ester was quantified by using Agilent technologies 6890N Gas Chromatography (AOCS official method ce1-62) with column no: DB-225MS, column length 30 mm, film thickness 0.25µm with temperature 40^{o}c to 24^{o}c with sigmoid as standard (IICT, Hyderabad). Based on the fatty acid profile two fat sources were blended to obtain desired UFA: SFA fatty acids ratio.

The broiler starter diet was formulated to contain 22% protein and 2950 kcal/kg ME so as to get 1:135 protein calorie ratio. Similarly the broiler finisher diet was formulated to contain 18% protein and 3100 kcal/kg ME so as to get 1:170 protein calorie ratio. The starter diet was fed up to four weeks of age and the finisher diet was fed during 5^{th} and 6^{th} week. The energy contributed by fat and or oil sources was kept constant for all the treatment groups.

3.4 Birds

480 one day old male Vencobb chicks were reared in battery brooders under identical managemental conditions till six week of age. Chicks were distributed randomly into twelve groups each with eight replicates each consist of five birds. The mean body weight for each group was kept nearly constant during distribution of birds. Feed and water were provided *ad lib* during entire experimental period. The birds were vaccinated against Ranikhet disease with Lasota at 7^{th} & 28^{th} day of age and against Gumboro vaccine (Georgia Strain) at

21st day of age through intraocular route. On 10th, 11th and 12th day of age Tiamutin was given as a preventive dose through drinking water.

3.5 Measurement of Response

3.5.1 Performance of broilers

The performance of broilers chicken was evaluated in terms of weekly body weight gain weekly feed intake as influenced by ratio of UFA: SFA and L-car supplementation to isocalorie and isonitrogenous diets during grower and finisher periods.

Individual body weight of birds was recorded at the beginning of experiment and weekly thereafter for calculating weight gain. Weekly feed intake was recorded for each replicate of each treatment group. The data on weight gain and feed intake for each replicate were used to calculate feed per gain.

3.5.2 Carcass yield and quality

One bird randomly selected per replicate making eight birds per treatment for slaughter, had free access to feed and water, in order to avoid a possible effect of feed withdrawal for a period of time on the fat content of liver, adipose tissue, to avoid masking of the effect of factors in question. Total 96 birds sacrificed in three days from 43rd to 45th day of age, similar number of birds each day per treatment were slaughtered for providing equal variation.

The parameters measured were weights and percentage, dressing yield, and ready to cook yield along with skin, giblets, breast yield including bone and skin, and abdominal fat content (as absolute weight and as a percentage of body weight)

following cervical dislocation. To ensure complete excision of abdominal fat pad carcass was scalded and chilled immediately in cold water tank.

Approximately 20-25g of dark and light muscle along with skin and liver samples were collected in a sealed polythene bag and preserved at 4^0c and further analyzed for percentage of dry matter, crude fat to know the effect L-car on redistribution of fat from adipose tissue to liver and muscle.

In order to examine the effect of L-car on assimilation of triglyceride, blood sample of 35^{th} and 43^{rd} day age of bird were collected from four bird per treatment by rupturing wing vein after 3hrs and 12hrs fasting respectively. The blood was allowed to clot for 4hrs then centrifuged for separation of serum and sample was preserved at -20^0c until analyzed for triglyceride and cholesterol.

3.6 Laboratory analysis

3.6.1 Moisture Percentage

The frozen samples of liver, light and dark muscles were dried at 65^0c in forced-draft oven until consecutive similar values were obtained. The moisture percentage was calculated by using the formula.

$$\text{Moisture \%} = \frac{\text{Weight of sample before drying} - \text{Weight of sample after drying}}{\text{Weight sample}} \text{ X } 100$$

3.6.2 Crude fat

After drying the samples were ground and preserved at 4^0c in a tight sealed bag until required for fat extraction. Crude fat percentage analysis was carried out according to the official methods of analysis (Association of Official Analytical

Chemist 1990). Three samples per treatment were analyzed for fat content. Fat percentage was calculated using following formula

$$\text{Crude fat\%} = \frac{\text{Initial weight of extraction flask} - \text{Final weight of extraction flask}}{\text{Weight of sample}} \text{ X } 100$$

3.6.3 Serum lipid profile

Serum triglyceride and cholesterol were estimated by using mass spectrophotometer with commercially available kit (Qualigens) method.

3.7 Statistical analysis

The data were analysed using General Linear Model procedure of Statistical Package for Social Sciences (SPSS) 16^{th} version and comparison of means tested using Duncan's multiple range test and significance was considered at $P<0.05$.

CHAPTER IV

RESULTS

The results of the present experiment have been presented in two parts for the convenience of discussion. Part one deals with fatty acid composition of supplemental fats and effect of fat source, whereas part two deals with the effect of the ratio of UFA: SFA with or without L-carnitine supplementation on the performance parameters of economic importance in broilers and carcass yields and qualitative characters of broiler meat.

PART I

4.1 Fatty Acid Composition of supplemental fats

The fatty acid composition of supplemental fats were determined by Agilent technologies 6890N Gas Chromatography.

4.1.1 Fatty acid profile of Crude Soybean Oil and Tallow

Fatty acid profile in crude soybean oil (CSBO) and tallow (TAL) are presented in Table 11. The values of saturated fatty acids i.e., palmitic, stearic, arachidic and behenic were found to be 11.95, 3.03, 0.3 and 0.41%, while values of unsaturated fatty acids (UFA) palmitoleic, oleic, linoleic, linolenic were 0.11, 25.33, 52.26 and 6.57% respectively. From this analysis it can be observed that CSBO is rich in its UFA compared to SFA especially linoleic acid (18:2) followed by oleic acid (18:1). On the other hand the SFA i.e., palmitic acid and stearic acid constitute a major amount than other saturated fatty acids being 11.95 and 3.03%, respectively.

From the results it can be noticed that TAL contains high amount of saturated fatty acids (56.60%), monounsaturated fatty acids (41.37%) and lower

Table 11: Fatty acid (%) profile of experimental fat source

Fatty Acid	no of carbon Atoms	Sources of Fat	
		CSBO	TAL
Lauric	C 12:0	n.d	0.07
Myristic	C 14:0	n.d	2.26
Pentadecylic	C 15:0	n.d	0.67
Palmitic	C 16:0	11.95	25.05
Palmitoleic	C 16:1	0.11	2.32
Margaric	C 17:0	n.d	1.84
Stearic	C 18:0	3.03	26.35
Oleic	C 18:1	25.33	39.05
Linoleic	C 18:2	52.26	1.67
Linolenic	C 18:3	6.57	0.31
Arachidic	C 20:0	0.30	0.36
Behenic	C 22:0	0.41	n.d
ΣSFA		15.69	56.60
ΣUFA		84.27	43.35
UFA/SFA		5.37	0.77
ΣMUFA		25.44	41.37
ΣPUFA		58.83	1.98
n3		6.57	0.31
n6		52.26	1.67
n3/n6		0.13	0.19

n.d : not detected
SFA : saturated fatty acids
UFA : unsaturated fatty acids
MUFA : monounsaturated fatty acids
PUFA : polyunsaturated fatty acids
n-3 : omega -3 fatty acids
n-6 : omega-6 fatty acids

levels of polyunsaturated fatty acids (1.98%) when compared with CSBO (15.69%, 25.44% and 58.83% respectively). From the data palmitic acid and stearic acid were major constituents of saturated fatty acids being 25.05% and 26.35% respectively. Oleic acid (39.05%), a monounsaturated fatty acid, constitutes higher proportion of unsaturated fatty acid and proportion of polyunsaturated fatty acids was less 1.98%.

4.2 Effect of fat source with or without L-carnitine

4.2.1 Performance

4.2.1.1 Body Weight Gain

As a source of energy CSBO gave, significantly ($P<0.05$) better weight gains (2135g) than tallow (2103g). Supplementation of L-car (100mg/kg) significantly ($P<0.05$) resulted in better body weight gain during finisher phase. However during starter phase and overall period (0-42 days) it was numerically better. The values were significantly ($P<0.05$) recorded superior with L-car supplementation for crude soybean oil (Table 12) while reverse trend was observed with L-car supplementation for tallow. Almost similar trend in body weight gains was observed during starter phase but with marginal variations. However the trend was not similar in finisher phase. Interaction effect was significant ($P<0.05$) during all the periods.

4.2.1.2 Feed Consumption

Feed intake was significantly ($P<0.05$) high for CSBO than TAL during starter phase (0-28 days). The feed intake during finisher and overall period was not significantly ($P>0.05$) influenced by fat source (Table 13).

Table 12: Effect of TAL and CSBO with or without L-carnitine on body weight gain

Treatment	L-car	Body weight gain(g)/bird		
		0-28 days	28-42 days	0-42 days
TAL	0	1205[b]	918[a]	2123[b]
CSBO	0	1240[a]	860[b]	2099[bc]
TAL	100	1174[c]	909[a]	2083[c]
CSBO	100	1244[a]	927[a]	2171[a]
Effect of fat source				
TAL		1190[b]	913	2103[b]
CSBO		1242[a]	893	2135[a]
Effect of L-car (mg/kg)				
0		1223	889[b]	2111
100		1209	918[a]	2127
SEM		**5.954**	**6.714**	**7.370**
Source of variance *p* value				
Fat * L-car		0.012	0.001	0.001
Fat source		0.001	0.059	0.002
L-car		0.052	0.007	0.091

Values bearing different superscripts with in a column are significantly ($P < 0.05$) different

Table 13: Effect of TAL and CSBO with or without L-carnitine on feed consumption

Treatment	L-car	Feed consumption (g)/bird		
		0-28 days	28-42 days	0-42 days
TAL	0	1836	2265[a]	4101[a]
CSBO	0	1901	2158[b]	4060[a]
TAL	100	1783	2192[b]	3976[b]
CSBO	100	1838	2222[ab]	4060[a]
Effect of fat source				
TAL		1810[b]	2229	4038
CSBO		1870[a]	2190	4060
Effect of L-car (mg/kg)				
0		1868[a]	2211	4080[a]
100		1810[b]	2207	4018[b]
SEM		**50.114**	**75.086**	**80.054**
Source of variance *p* value				
Fat * L-car		0.557	0.007	0.016
Fat source		0.001	0.111	0.387
L-car		0.001	0.856	0.016

Values bearing different superscripts with in a column are significantly ($P < 0.05$) different

The effect of carnitine on feed intake reduced significantly (P<0.05) during starter and overall period by adding 100 mg/kg L-car.

The interaction effect was significant (P<0.05) only during finisher and overall period. The feed consumption of birds was significantly (P<0.05) higher for CSBO with or without L-car (4060g) similar to tallow without L-car (4101g).

4.2.1.3 Feed per Gain

Feed per gain was significantly (P<0.05) better for crude soybean oil than tallow (Table 14) during starter and overall periods of the experiment.

Significantly (P<0.05) better FCR was observed by supplementing L-car during starter, finisher and overall periods. The feed per gain at 100 and 0 mg/kg L-car was 1.50, 2.41 and 1.89 vs 1.53, 2.49 and 1.93 for starter, finisher and overall period of experiment respectively.

The interaction between sources of energy and L-car was significant only during 0-28 days and 0-42 days of age. Feed per gain for starter, finisher and over all period (0-42 days) was significantly (P<0.05) better for birds fed with diet containing crude soybean oil with L-car (1.48, 2.40 and 1.87 respectively) than for tallow with L-car (1.52, 2.41 and 1.91 respectively).

4.2.2 Carcass Parameters

4.2.2.1 Carcass yields

Factorial analysis showed dressing, giblet, ready to cook (R to C) and breast yield (Table 15) as percentage of live weight was not significantly (P>0.05) influenced by fat source with or without L-car.

Table 14: Effect of TAL and CSBO with or without L-carnitine on feed per gain

Treatment	L-car	Feed/ gain		
		0-28 days	28-42 days	0-42 days
TAL	0	1.52[b]	2.47	1.93[a]
CSBO	0	1.53[a]	2.51	1.93[a]
TAL	100	1.52[b]	2.41	1.91[b]
CSBO	100	1.48[c]	2.40	1.87[c]
Effect of fat source				
TAL		1.52[a]	2.44	1.92[a]
CSBO		1.51[b]	2.45	1.90[b]
Effect of L-car (mg/kg)				
0		1.53[a]	2.49[a]	1.93[a]
100		1.50[b]	2.41[b]	1.89[b]
SEM		**0.025**	**0.065**	**0.034**
Source of variance *p* value				
Fat * L-car		0.001	0.143	0.016
Fat source		0.003	0.437	0.029
L-car		0.001	0.001	0.001

Values bearing different superscripts with in a column are significantly ($P < 0.05$) different

Table 15: Effect of TAL and CSBO with or without L-carnitine on carcass yields

Treatment	L-car	% of Yield				
		Dressing[1]	R to C[1]	Giblet	Abdominal fat	Breast [2]
TAL	0	85.73	77.56	4.05	2.25[a]	21.28
CSBO	0	85.69	76.39	4.32	1.77[b]	20.22
TAL	100	85.38	76.66	4.48	1.89[b]	21.16
CSBO	100	85.60	76.73	4.44	2.19[a]	20.71
Effect of fat source						
TAL		85.56	77.11	4.27	2.07	21.22
CSBO		85.45	76.56	4.38	1.98	20.47
Effect of L-car (mg/kg)						
0		85.71	76.98	4.19	2.01	20.75
100		85.49	76.70	4.46	2.04	20.93
SEM		**0.873**	**1.732**	**0.432**	**0.046**	**0.302**
Source of variance *p* value						
Fat * L-car		0.683	0.326	0.290	0.001	0.618
Fat source		0.783	0.383	0.442	0.133	0.231
L-car		0.506	0.657	0.070	0.575	0.766

Values bearing different superscripts with in a column are significantly ($P < 0.05$) different, [1]with skin, [2] with skin and bone.

Similarly abdominal fat percentage was not significantly (P>0.05) influenced by either fat source or carnitine supplementation. However supplementing unsaturated fat resulted slight reduction of abdominal fat percentage than saturated fats (1.98 vs 2.07%). The interaction effect was significant (P<0.05) indicating tallow diet supplementation with 100 mg/kg L-car resulted in significant reduction of abdominal fat but reverse trend was seen with crude soybean oil.

4.2.2.2 Moisture percentage

Liver moisture percentage was significantly (P<0.05) high for TAL fed group than CSBO. Effect of carnitine on liver moisture percentage was significantly (P<0.05) high at 100 mg/kg L-car supplementation (Table 16). Interaction effect was significant (P<0.05) and there was significant increase in moisture content of liver by supplementing 100 mg/kg L-car for CSBO diets but not for TAL diets.

Moisture percentage of light muscle was not significantly (P>0.05) influenced by fat source and carnitine supplementation (Table 16), however interaction effect was significant (P<0.05). The moisture content of light muscle was significantly (P<0.05) increased by adding 100 mg/kg L-car to TAL group compared to CSBO fed group.

Dark muscle moisture percentage was significantly (P<0.05) high for CSBO fed group when compared to TAL fed birds (70.42 vs 68.49%). Effect of carnitine on dark muscle moisture percentage was significantly (P<0.05) low at 100 mg/kg L-car. Interaction effect was significant (P<0.05) which was evidenced for CSBO fed groups when supplemented with L-car whereas TAL fed groups did not have significant effect when L-car was added to these group.

Table 16: Effect of TAL and CSBO with or without L-carnitine on moisture and fat content of liver, light and dark muscle of broilers

Treatment	L-car	Moisture percentage[1]			Fat percentage[2]		
		Liver	Light muscle[3]	Dark muscle[3]	Liver	Light muscle[4]	Dark muscle[4]
TAL	0	69.17^{a}	65.21^{b}	68.47^{c}	9.62	12.75^{a}	13.43^{b}
CSBO	0	68.13^{b}	66.46^{a}	71.58^{a}	10.97	9.89^{c}	12.92^{c}
TAL	100	69.47^{a}	66.55^{a}	68.50^{c}	13.17	11.73^{b}	13.81^{ab}
CSBO	100	69.25^{a}	65.72^{ab}	69.27^{b}	14.94	11.46^{b}	14.30^{a}
Effect of fat source							
TAL		69.32^{a}	65.88	68.49^{b}	11.40^{b}	12.24^{a}	13.62
CSBO		68.69^{b}	66.09	70.42^{a}	12.96^{a}	10.68^{b}	13.61
Effect of L-car (mg/kg)							
0		68.65^{b}	65.83	70.02^{a}	10.30^{b}	11.32^{b}	13.18^{b}
100		69.36^{a}	66.14	68.89^{b}	14.06^{a}	11.60^{a}	14.06^{a}
SEM		**0.121**	**0.198**	**0.232**	**0.635**	**0.312**	**0.166**
Source of variance *p* value							
Fat * L-car		0.019	0.008	0.001	0.592	0.001	0.012
Fat source		0.001	0.562	0.001	0.003	0.001	0.950
L-car		0.001	0.406	0.001	0.001	0.032	0.001

Values bearing different superscripts with in a column are significantly ($P < 0.05$) different

[1]number of sample were eight per treatment,

[2]number of sample were three per treatment,

[3 and 4]moisture and fat percentage for muscles analyzed along with skin

4.2.2.3 Fat content of liver, light and dark muscle

Dietary treatment showed significant effect on fat content of liver, light and dark muscles (Table 16). Liver fat percentage was significantly ($P<0.05$) increased by dietary addition of CSBO (12.96 vs 11.40% for TAL respectively). Fat content of light muscle was significantly ($P<0.05$) high for tallow fed groups than soybean oil (12.24 vs 10.68% and 13.62 vs 13.61%), whereas dark muscle fat content was not significantly ($P>0.05$) influenced by fat source.

Addition of L-car had significantly ($P<0.05$) increased fat percentage of liver, light and dark muscles (14.06 vs 10.30%; 11.60 vs 11.32% and 14.06 vs 13.18% for 0 mg/Kg L-car respectively).

Interaction effect was significant ($P<0.05$) for fat percentage of light and dark muscles but liver fat content was not significantly ($P>0.05$) influenced. Fat percentage of light muscle was significantly ($P<0.05$) low for the CSBO without carnitine (9.89%) followed by TAL and CSBO with L-car supplementation (11.46 and 11.73% respectively). Fat content of dark muscle was significantly increased by adding L-car either to CSBO or TAL diets.

4.2.3 Serum lipid profile

4.2.3.1 Serum Triglyceride

Serum triglyceride was high for broilers fed with unsaturated fat (CSBO) than TAL (71.46 vs 64.86 mg/dl respectively) after 3 hours of fasting and significantly ($P<0.05$) decreased after 12 hours of fasting (14.75 vs 19.91 mg/dl). Supplementing L-car, significantly ($P<0.05$) reduced serum triglycerides concentration at 3 and 12 hours of fasting (49.41 and 15.73 mg/dl). The interaction

between energy sources and L-car was also significant (P<0.05) at 3hr and 12hr fasting on serum triglyceride concentrations (Table 17).

4.2.3.2 Serum Cholesterol

Effect of fat source on serum cholesterol concentration was significantly (P<0.05) high for CSBO (179.16 mg/dl) than TAL (159.16 mg/dl). Dietary supplementation of L-car reduced significantly (P<0.05) serum cholesterol concentration (161.66 vs 179.16 without L-car respectively). The interaction effect was not significant (P>0.05), Table 17.

Table 17: Effect of TAL and CSBO with or without L-carnitine on blood parameters

Treatment	L-car	Triglyceride[1](mg/dl)		Cholesterol[1](mg/dl)
		3hrs fasting	12hrs fasting	3hrs fasting
TAL	0	85.93[a]	23.10[a]	167.50
CSBO	0	87.88[a]	14.76[b]	185.83
TAL	100	43.79[c]	16.72[b]	150.83
CSBO	100	55.04[b]	14.74 [b]	172.48
Effect of fat source				
TAL		64.86[b]	19.91[a]	159.16[b]
CSBO		71.46[a]	14.75[b]	179.16[a]
Effect of L-car (mg/kg)				
0		86.90[a]	18.93[a]	176.66[a]
100		49.41[b]	15.73[b]	161.66[b]
SEM		**4.9741**	**0.9461**	**3.3951**
Source of variance *p* value				
Fat * L-car		0.001	0.001	0.487
Fat source		0.001	0.001	0.001
L-car		0.001	0.001	0.001

Values bearing different superscripts with in a column are significantly ($P < 0.05$) different
[1]number of sample analyzed was four per treatment

Part II

4.2 Effect of ratio of Unsaturated to Saturated fatty acid with or without L-Carnitine

4.2.1 Performance

4.2.1.1 Body Weight Gain

The main effect of UFA: SFA ratio on body weight gain was significantly ($p<0.05$) different (Table 18) for broilers fed diet containing different ratios of unsaturated to saturated fatty acids (UFA: SFA). Significantly ($P<0.05$) highest weight gain was recorded at 70:30 ratio of UFA: SFA either during starter period or finisher period (1235 and 949g respectively) and lowest at 75:25 ratio of UFA: SFA (1208 vs 899g, starter and finisher periods respectively).

The broilers supplemented with dietary L-car showed significant ($p<0.05$) reduction in weight gain during starter and finisher periods (1207 vs 1243g and 910 vs 933g respectively), resulting in similar pattern at 42 days of age (2117 vs 2176g).

The interaction effect of UFA: SFA with L-car on body weight gain of broilers during starter, finisher and overall treatment periods (0-42 days) was also significant. The growth rate was significantly ($P<0.05$) higher for broilers fed on diets containing different UFA: SFA ratios without L-car than with 100mg/kg L-car supplementation. Significantly the highest growth was observed at 70:30 (2221g) followed by 60:40 UFA: SFA without L-car (2183g) respectively.

4.2.1.2 Feed Consumption

Effect of UFA: SFA ratio when considered, there was gradual increase in the feed consumption with increase in unsaturation of supplemental fat except at 75:25 ratio of

Table 18: Effect of ratio of UFA: SFA with or without L-carnitine on body weight gain

Treatment	L-car	Body weight gain(g)/bird		
		0-28 days	28-42 days	0-42 days
60:40	0	1237^{ab}	912^{b}	2149^{b}
65:35	0	1258^{a}	924^{b}	2182^{b}
70:30	0	1246^{ab}	975^{a}	2221^{a}
75:25	0	1232^{b}	921^{b}	2153^{b}
60:40	100	1229^{b}	955^{a}	2185^{b}
65:35	100	1191^{c}	885^{c}	2077^{c}
70:30	100	1223^{b}	924^{b}	2147^{b}
75:25	100	1184^{c}	876^{c}	2060^{c}
Effect of UFA:SFA ratio				
60:40		1233^{a}	934^{a}	2167^{a}
65:35		1225^{a}	905^{b}	2129^{b}
70:30		1235^{a}	949^{a}	2184^{a}
75:25		1208^{b}	899^{b}	2107^{b}
Effect of L-Car (mg/kg)				
0		1243^{a}	933^{a}	2176^{a}
100		1207^{b}	910^{b}	2117^{b}
SEM		**3.895**	**4.879**	**7.573**
Source of variance *p* value				
UFA:SFA ratio* L-Car		0.001	0.001	0.001
UFA:SFA ratio		0.003	0.001	0.001
L-Car		0.001	0.001	0.001

Values bearing different superscripts with in a column are significantly (P < 0.05) different

UFA: SFA (Table 19) during finisher and overall period of the experiment. The same trend was not found during starter phase. And the birds fed with diets supplemented with L-car showed lower feed intake either during starter or finisher period (1828 vs 1860g and 2291 vs 2299g respectively) but difference was significant only for starter phase.

Interaction between ratio of UFA: SFA and L-car was evident throughout the experiment period i.e. starter, finisher and overall period for feed consumption. Significantly ($P<0.05$) the lowest feed intake was noticed at 75:25 with L-car supplementation (4005g).

4.2.1.3 Feed per Gain

During 28-42 days and 0-42 days of age the feed efficiency in groups fed 60:40 was significantly ($P<0.05$) better (Table 20) compared to those fed with higher UFA: SFA ratio. During 28-42 days the feed per gain at 70:30 was intermediate to the other ratios. However better feed efficacy was found at 75:25 ratio (1.47) during starter period.

The feed efficiency in L-car supplemented groups was significantly ($P<0.05$) inferior (2.52, 1.95) to those fed without L-car (2.46 and 1.91) during 28-42 days and 0-42 days of age respectively.

Interaction between UFA: SFA ratio and L-car supplementation significantly ($P<0.05$) influenced feed per gain at starter period but not at finisher and overall period (0-42 days). Form the interaction effect it was clear that adding L-car resulted in better performance at 75:25 ratio (1.46 vs 1.49) and reverse trend was seen at 70:30 ratio (1.58 vs 1.50) during starter period whereas it had resulted in poor FCR during finisher and overall period.

Table 19: Effect of ratio of UFA: SFA with or without L-carnitine on feed consumption

Treatment	L-car	Feed consumption (g)/bird		
		0-28 days	28-42 days	0-42 days
60:40	0	1861^{bc}	2185^{c}	4046^{cd}
65:35	0	1884^{b}	2341^{ab}	4225^{a}
70:30	0	1864^{bc}	2374^{a}	4238^{a}
75:25	0	1830^{c}	2295^{ab}	4125^{bc}
60:40	100	1853^{bc}	2329^{ab}	4182$^{a\ b}$
65:35	100	1787^{d}	2260^{bc}	4047^{cd}
70:30	100	1939^{a}	2300^{ab}	4239^{a}
75:25	100	1732^{e}	2273^{b}	4005^{d}
Effect of UFA:SFA ratio				
60:40		1857^{b}	2257^{b}	4114^{bc}
65:35		1836^{b}	2301^{ab}	4136^{b}
70:30		1902^{a}	2337^{a}	4239^{a}
75:25		1781^{c}	2284^{ab}	4070^{c}
Effect of L-car (mg/kg)				
0		1860^{a}	2299	4159
100		1828^{b}	2291	4118
SEM		**8.556**	**11.244**	**15.687**
Source of variance *p* value				
UFA:SFA ratio* L-Car		0.001	0.001	0.001
UFA:SFA ratio		0.001	0.032	0.001
L-Car		0.001	0.671	0.086

Values earing different superscripts with in a column are significantly ($P < 0.05$) different

Table 20: Effect of ratio of UFA: SFA with or without L-carnitine on feed per gain

Treatment	L-car	Feed /gain		
		0-28 days	28-42 days	0-42 days
60:40	0	1.51[b]	2.40	1.88
65:35	0	1.50[b]	2.53	1.94
70:30	0	1.50[b]	2.44	1.91
75:25	0	1.49[b]	2.49	1.92
60:40	100	1.51[b]	2.44	1.91
65:35	100	1.50[b]	2.55	1.94
70:30	100	1.58[a]	2.49	1.97
75:25	100	1.46[c]	2.60	1.94
Effect of UFA: SFA ratio				
60:40		1.51[b]	2.42[c]	1.90[b]
65:35		1.50[b]	2.54[a]	1.94[a]
70:30		1.54[a]	2.46[b]	1.94[a]
75:25		1.47[c]	2.54[a]	1.93[a]
Effect of L-car(mg/kg)				
0		1.50[b]	2.46[b]	1.91[b]
100		1.51[a]	2.52[a]	1.95[a]
SEM		**0.037**	**0.084**	**0.036**
Source of variance *p* value				
UFA: SFA ratio* L-car		0.001	0.254	0.062
UFA: SFA ratio		0.001	0.001	0.001
L-car		0.001	0.001	0.001

Values bearing different superscripts with in a column are significantly ($P < 0.05$) different

4.2.2 Carcass Parameters

4.2.2.1 Carcass yields

The slaughter variables studied were not affected by supplementing the diet with different UFA: SFA ratio or supplementation of L-car, except abdominal fat which was influenced by the ratio of UFA: SFA. The abdominal fat percentage was lowest with 75:25 ratio diet fed birds (Table 21).

Interaction between UFA: SFA ratio and L-car supplementation did not influence the slaughter variables except the abdominal fat percentage. Deposition of fat in abdominal area increased significantly ($P<0.05$) with L-car supplementation to diets containing 60:40 ratio. At 70:30 ratio L-car supplementation significantly ($P<0.05$) reduced fat deposition in abdominal area. At other ratios of UFA: SFA, supplementation of L-car failed to influence the abdominal fat content.

4.2.2.2 Moisture percentage

Moisture percentage of liver was significantly ($P>0.05$) high at 60:40 ratio and there was decreasing trend in moisture content of liver as the unsaturation of supplemental fat increased. The moisture content of liver was not significantly ($P>0.05$) influenced by L-car supplementation, whereas moisture content was significantly ($P<0.05$) influenced by the interaction. The moisture percentage is significantly high at 60:40 ratio without L-car.

Moisture percentage of light and dark muscles with intact skin was significantly ($P<0.05$) influenced by the fat source, L-car and in combination (Table 22). There was no significant dose dependent response. Significantly higher moisture content was observed at 65:35 and 70:30 ratio of UFA: SFA for light and

Table 21: Effect of ratio of UFA: SFA with or without L-carnitine on yields

	L-car	% of Yield			
		R to C[1]	Giblet	Abdominal fat	Breast[2]
60:40	0	77.42	4.39	2.01[b]	21.83
65:35	0	77.29	4.17	1.71[c]	21.00
70:30	0	77.04	4.19	2.05[b]	20.49
75:25	0	76.89	4.07	1.80[c]	21.03
60:40	100	77.29	4.18	2.31[a]	20.43
65:35	100	76.84	4.20	1.87[bc]	21.20
70:30	100	77.62	4.03	1.81[c]	21.04
75:25	100	77.14	4.20	1.71[c]	21.31
Effect of UFA: SFA ratio					
60:40		77.36	4.28	2.16[a]	21.13
65:35		77.07	4.19	1.79[c]	21.09
70:30		77.33	4.11	1.93[b]	20.76
75:25		77.02	4.14	1.75[c]	21.17
Effect of L-car (mg/kg)					
0		77.16	4.203	1.90	21.09
100		77.22	4.154	1.92	20.99
SEM		**0.185**	**0.048**	**0.032**	**0.189**
Source of variance *p* value					
UFA: SFA ratio* L-car		0.800	0.597	0.001	0.277
UFA: SFA ratio		0.890	0.619	0.001	0.870
L-car		0.872	0.624	0.551	0.804

Values bearing different superscripts with in a column are significantly ($P < 0.05$) different, [1]with skin, [2] with skin and bone.

dark muscles respectively. Carnitine supplementation significantly reduced moisture content in light muscle, whereas a reverse trend was observed for dark muscle. Form the interaction data, the moisture content of dark muscle was increased by carnitine supplementation at 70:30 and 75:25 ratio of UFA: SFA.

4.2.2.3 Fat content of liver, light and dark muscle

Dietary treatment had significant ($P<0.05$) effect on fat percentage of liver, light and dark muscles along with skin (Table 22). The fat content was significantly ($P<0.05$) effected by ratio of UFA: SFA and significantly lower liver fat and higher muscle fat percentage were observed at 75:25 ratios when compared to other ratios.

The effect of L-car on reduction of fat content was significant ($p<0.05$) for liver and light muscle whereas for dark muscles supplementing 100 mg/kg L-car significantly ($P<0.05$) increased fat percentage (Table 22). There was significant ($P<0.05$) interaction effect for fat percentage of liver, light and dark muscles. Interaction data indicated that fat percentage was significantly ($P<0.05$) high for ratio of UFA: SFA without carnitine supplementation.

4.2.3 Serum lipid profile

4.2.3.1 Serum Triglyceride

There was significant ($P<0.05$) influence of dietary treatment, UFA: SFA ratio and L-car alone or in combination on serum triglyceride levels (Table 23), but no clear trend was observed. As unsaturation of fatty acid increased in the fat blends, there was decrease in triglyceride values at 3hrs fasting and same trend was seen after 12hrs fasting. However lowest level of triglycerides was observed at

75:25 (43.08 mg/dl) and 70:30 UFA: SFA ratio (16.11 mg/dl) at 3 and 12 hours fasting respectively. Addition of L-car significantly ($P<0.05$) lowered serum triglycerides at 3 and 12 hrs fasting.

The interaction between UFA: SFA and supplementation of L-car significantly influenced the concentration of triglycerides in serum at 3 and 12 hrs fasting. At 3 hrs post fasting, concentration of triglycerides in serum decreased significantly ($P<0.05$) at all ratios of UFA: SFA with supplementation of L-car. Similar trend was observed at 60:40 and 75:25 ratio.

Table 22: Effect of ratio of UFA: SFA with or without L-carnitine on moisture and fat content of liver, light and dark muscle

Treatment	L-car	Moisture percentage[1]			Fat percentage[2]		
		Liver	Light muscle[3]	Dark muscle[3]	Liver	Light muscle[4]	Dark muscle[4]
60:40	0	70.39^{a}	67.16^{b}	68.13^{d}	12.61^{ab}	8.88^{e}	12.98^{e}
65:35	0	70.39^{a}	68.63^{a}	68.18^{d}	11.73^{bcd}	10.10^{b}	14.68^{bc}
70:30	0	68.27^{c}	68.52^{a}	69.81^{b}	13.62^{a}	9.14^{c}	13.07^{e}
75:25	0	68.42^{c}	67.18^{b}	68.74^{c}	9.55^{e}	13.49^{a}	15.27^{a}
60:40	100	69.71^{ab}	66.60^{c}	66.09^{e}	11.13^{cd}	9.18^{c}	14.46^{c}
65:35	100	68.30^{c}	67.40^{b}	69.50^{b}	12.26^{bc}	9.06^{cd}	14.38^{c}
70:30	100	69.05^{bc}	66.38^{c}	70.29^{a}	9.45^{e}	8.9^{de}	13.46^{d}
75:25	100	69.13^{bc}	68.62^{a}	70.30^{a}	10.50^{de}	9.23^{c}	14.87^{b}
Effect of UFA: SFA ratio							
60:40		70.05^{a}	66.88^{c}	67.11^{d}	11.87^{a}	9.03^{c}	13.72^{c}
65:35		69.34^{ab}	68.01^{a}	68.84^{c}	12.10^{a}	9.58^{b}	14.53^{b}
70:30		68.66^{b}	67.45^{b}	70.05^{a}	11.54^{a}	9.02^{c}	13.26^{d}
75:25		68.78$^{\mathbf{b}}$	67.90^{a}	69.52^{b}	10.02^{b}	11.36^{a}	15.07^{a}
Effect of L-car (mg/kg)							
0		69.37	67.87^{a}	68.71^{b}	11.88^{a}	10.40^{a}	14.00^{b}
100		69.05	67.25^{b}	69.05^{a}	10.83^{b}	9.09^{b}	14.29^{a}
SEM		**0.171**	**0.123**	**0.172**	**0.312**	**0.305**	**0.172**
Source of variance *p* value							
UFA: SFA ratio* L-car		0.002	0.001	0.001	0.001	0.001	0.001
UFA: SFA ratio		0.005	0.001	0.001	0.001	0.001	0.001
L-car		0.270	0.001	0.001	0.002	0.001	0.005

Values bearing different superscripts with in a column are significantly ($P < 0.05$) different, [1]number of sample were eight per treatment, [2]number of sample were three per treatment, [3 and 4]moisture and fat percentage for muscles analyzed along with skin

Table 23: Effect of ratio of UFA: SFA with or without L-carnitine on blood parameters

Treatment	L-car	Triglyceride[1](mg/dl)		Cholesterol[1](mg/dl)
		3hrs fasting	12hrs fasting	3hrs fasting
60:40	0	84.48[a]	34.69[a]	171.66[c]
65:35	0	56.86[b]	18.65[c]	181.65[b]
70:30	0	57.00[b]	16.40[de]	143.32[e]
75:25	0	55.58[b]	21.12[b]	198.33[a]
60:40	100	33.43[e]	20.12[bc]	169.16[c]
65:35	100	37.17[d]	18.21[cd]	143.33[e]
70:30	100	40.86[c]	15.82[e]	135.00[f]
75:25	100	30.59[f]	16.42[de]	156.65[d]
Effect of UFA: SFA ratio				
60:40		58.95[a]	27.40[a]	170.41[b]
65:35		47.01[c]	18.43[b]	162.49[c]
70:30		48.93[b]	16.11[c]	139.16[d]
75:25		43.08[d]	18.77[b]	177.49[a]
Effect of L-car (mg/kg)				
0		63.48[a]	22.71[a]	173.74[a]
100		35.51[b]	17.64[b]	151.03[b]
SEM		**2.999**	**1.052**	**3.721**
Source of variance *p* value				
UFA: SFA ratio* L-car		0.001	0.001	0.001
UFA: SFA ratio		0.001	0.001	0.001
L-car		0.001	0.001	0.001

Values bearing different superscripts with in a column are significantly ($P < 0.05$) different, [1]number of sample analyzed was four per treatment

CHAPTER V

DISCUSSION

This chapter deals with discussion of results which are presented in two parts. First part deals with fatty acid composition of supplemental fats, effect of fat source and second part deals with effect of ratio of UFA: SFA with or without L-carnitine supplementation.

PART I

5.1.1 Fatty Acid Composition of Supplemental Fats

UFA and SFA present in CSBO (84.27 and 15.69% respectively), in the present experiment is almost similar to those of findings of the other authors (Balevi and Coskun, 2000; Mossab *et al.,* 2000; Rondelli *et al.,* 2004; Waldroup and Waldroup, 2005) with slight variations. The proportion of linoleic acid (18:2), linolenic acid (18:3) and UFA: SFA ratio in CSBO was higher (Table 11) than those of the findings of Azman *et al.,* 2005 (Table 7). The difference in fatty acid profile of soybean oil may be attributed to genotype and environmental interaction. Furthermore, Jeong-Dong Lee *et al.,* (2007) indicated that soybean grown under high average temperatures have reduced 18:2, 18:3 and increased 18:1 content; however contents of saturated fatty acids were changed little by the environment.

The results of UFA: SFA ratio for tallow in the present experiment was 0.77, which are in partial accordance with Balevi and Coskun (2000); Mossab *et al.,* (2000) and Crespo *et al.,* (2002b). From the results (Table 11), it can be noticed that TAL contains higher levels of stearic acids when compared to the literature (Table 8). The difference in fatty acid profile of animal fat can be attributed to the diet, age and environmental conditions and mostly tissue involved in the rendering process (Taher Rabbie, 2005).

Effect of Fat source with or without L-carnitine

5.1.2 Performance Parameters

5.1.2.1 Body Weight Gain

The body weight in broiler chicks fed CSBO was significantly ($P<0.05$) higher than that of TAL fed group at 28 days of age. The lower body weight gain in TAL groups (Table 12) could be due to higher proportion of SFA and also due to inadequate secretion of lipase enzyme and bile salts during the initial juvenile phase (Wiseman, 2003). Similarly, lower digestibility for TAL (49.1%) compared to CSBO (86.4%) in young chicks was also reported by Mossab *et al* (2000).

The body weight gain during finisher phase was similar between the TAL and CSBO fed groups. The increased secretion of lipase enzyme with increase in the age of the bird as reported by Mossab *et al* (2000) might be responsible for the increased digestibility and utilization of fatty acids of TAL. Contradictory to these findings, Azman *et al.* (2005) reported significantly higher body weight gain in broiler fed TAL compared to those fed SBO in finisher phase. Variation in the composition of diet and period of feeding finisher diet might be responsible for the difference observed between the present study and the above report.

In the overall period, the body weight gain in broilers fed CSBO was significantly higher compared to those fed TAL. Though the body weight gain during the finisher phase was not affected due to the variation in source of oil, the better utilization of soy oil compared to TAL (Mossab *et al.,* 2000) during juvenile phase might have resulted in significant higher weight gain compared to those fed TAL which in turn reflected in higher body weight gain in soy oil fed birds compared to TAL. Similarly, Yamany *et al.* (2008) also reported significantly higher body weight gain in quails fed diets with higher proportion of unsaturated

fats compared to those fed with saturated fats. Contradictory to the present findings, Sibbald (1962) and Sanz *et al.* (1999) reported lack of significant influence of fat source on body weight gain in broiler chicks. They further reiterated the importance of energy to protein ratio which is more critical than fat source per se.

Supplementation of L-car did not show any positive effect on body weight gain during the starter or overall period (0-42 days). Similarly experiment conducted by Sarica *et al.* (2007) in quails using two different energy levels (2897 and 2799 kcal/kg ME), two PUFA oils (sunflower and fish oil) and L-car (0 and 50 mg/kg) found that there was no significant effect of L-car on body weight gain. However significant improvement in growth was observed during the finisher phase. The significant response observed during the finisher phase might be due to the higher quantity of supplemental fat (3.6 to 4.6%) in finisher diet compared to the starter phase (2.87 to 3.28%), in the present study (Table 9 and 10). Similar to the present findings, Rabie and Szilágyi (1998) found significant improvement in body weight gain of broiler during 18-32 days of age compared to those fed carnitine un-supplemented diets. The higher energy requirement during rapid growth phase (finisher period) might be facilitated by supplementing L-car which is known to play critical role in β-oxidation in the cell mitochondria. Similarly Haghighi Khoshkhoo *et al.*, (2006) stated that at the end of rearing period there is greater demand for energy and metabolic activity during rapid growth phase of broiler chicken. In humans Feller and Rudman (1988) reported reduced biosynthesis of carnitine during rapid growth phase (i.e. prematurity) and also reported the production of L-car during initial juvenile phase as adequate. In the present findings, there was lack of growth response in starter and significant

improvement in finisher diet. It also suggests the existence of similar such difference in carnitine production at different ages. However, there is no literature indicating similar such variation in biosynthesis of carnitine in chicks.

The interaction between sources of supplemental oil and carnitine supplementation significantly influenced body weight gain during starter, finisher and overall period. The data suggest that L-car supplementation significantly reduced the body weight gain in TAL fed birds but not CSBO fed groups during starter phase. Whereas during finisher phase and overall period carnitine supplementation significantly improved the body weight gain in soy oil fed birds. In TAL fed birds carnitine supplementation significantly depressed body weight gain during overall growth period. The interaction data thus indicates that the effect of carnitine supplementation on bird performance depends on source of oil and age of the bird.

5.1.2.2 Feed Consumption

Feed intake was significantly more ($P<0.05$) in CSBO than TAL fed groups during starter where as there was lack of significant ($P>0.05$) response during finisher and overall periods (0-42 days). These results are opposite to the findings of other authors (Balevi and Coskun, 2000; Sanz *et al.*, 2000a and 2002; Crespo and Esteve-Garcia, 2001; Newman *et al.*, 2002; Azman *et al.*, 2005) who reported higher feed intake in broiler fed on saturated fats than unsaturated fats. The higher feed intake in tallow fed birds might be due to lower calorific values of saturated fats present in tallow compared to those fed UFA. Relatively higher feed consumption was observed in the birds fed with TAL during finisher phase (Table 13). This might have resulted in greater weight gain than CSBO (Table 10).

Feed consumption was significantly (P<0.05) lower during starter and overall period with L-car supplementation (Table 13). Contradictory to our founding Rabie *et al.* (1998), indicated that there was increase in feed intake when L-car was supplemented. Whereas few authors (Xu *et al.* 2003; Sarica *et al.,* 2005 and 2007; Razaei *et al.,* 2007) reported that supplementing L-car did not have any significant effect on feed intake. The interaction data indicated significant response only during finisher and overall period (P=0.007 and P=0.016 respectively). Supplementation of L-car in TAL fed groups caused significant reduction in the feed consumption than those fed with CSBO.

5.1.2.3 Feed per Gain

The feed efficacy was significantly (P<0.05) higher in CSBO fed groups compared to TAL fed group. This might be partially due to higher feed intake (Table 14) and also better digestibility of unsaturated fats than saturated fats as reported (Mossab *et al.,* 2000). The results are in agreement with previous reporters (Zollitsch *et al.,* 1996; Balevi and Coskun, 2000; Newman *et al.* 2002).

The feed conversion ratio for either oil or fat without L-car was similar because there was no alteration between protein to energy ratio (1:170). So as long as this ratio is maintained, the performance was unaltered, as reported by Sibbald (1962).

Feed conversion ratio during starter, finisher and overall period was more efficient with L-car supplementation than without carnitine (Table 14). Rabie *et al.* (1998) found feed per gain was more efficient at 50 mg/kg L-car supplemented groups than without carnitine supplementation. On the contrary, Xu *et al.* (2003)

and Rezaei *et al.* (2007) reported lack of response in feed efficiency with carnitine supplementation at graded concentration.

The interaction between fat source and L-car was significant during starter and overall period of the experiment (Table 14). Feed conversion was better for unsaturated fats (CSBO) than saturated fats (TAL) when L-car was supplemented to these diets. Significant ($P<0.05$) interaction between dietary L-car and energy concentration, on body weight gain and feed conversion observed only during second week (25-32 days) of experimental period, was reported by Rabie *et al.* (1998). He also reported that carnitine supplementation was most effective at higher energy levels (3227 kcal/kg) than lower energy levels (3059 or 2916 kcal/kg) in diets. Similarly, Rezaei *et al.,* (2007) reported that interaction between carnitine and level of fat source was more efficient at 3% level of soy oil inclusion when compared with 5% or 1% level of soy oil inclusion.

5.1.3 Carcass Parameters

5.1.3.1 Carcass Yields

Relative weights of dressing, R to C, giblet and breast percentage were unaffected by treatments employed (Table 15). Earlier worker (Sanz *et al.,* 1999; Crespo and Esteve-Garcia, 2001; Rondelli *et al.*, 2004) reported that neither fat source nor the level of fat inclusion had any significant effect on dressing or carcass yields. Similarly carcass weight in broilers fed TAL and SBO did not differ significantly (Balevi and Coskun, 2000). However breast and thigh yields increased significantly with increase in the level of supplemental fat (Nyebpor *et al.*, 2007).

L-car supplementation could not influence the carcass variables studied (Table 15). Similarly few authors reported lack of significant effect of L-car on dressing percentage (Rabie *et al.,* 1998; Daskiran and Teeter, 2001; Sarica *et al.,* 2005) and other carcass traits like giblet, eviscerated and breast yields (Rabie *et al.,* 1998; Xu *et al.,* 2003; Rezaei *et al.,* 2007).

5.1.3.2 Abdominal Fat Percentage

The reduction in dietary carbohydrates and simultaneous increase in fat supplementation resulted in inhibition of *de novo* fatty acid synthesis. Therefore deposition of body fat (abdominal fat) depends directly upon intake of exogenous fatty acids. The body fat deposition depends upon the net balance among absorbed fat, endogenous fat synthesis and fat catabolism and abdominal fat has been shown to be positively correlated with total body fat (Becker *et al.* 1979).

The percentage of abdominal fat was not significantly ($P>0.05$) influenced by fat source (Table 15). Balevi and Coskun (2000) also reported that fat pad percentage was not significantly ($P>0.05$) reduced either by feeding TAL or SBO (2.08 and 1.90% respectively). Similarly other authors (Rondelli *et al.,* 2004; Nyebpor *et al.,* 2007) reported that neither fat source nor the level of fat inclusion effected the abdominal fat deposition. However the fatty acid composition of adipose tissue could be altered by the source of oil supplemented (Valencia *et al.* 1993).

Dietary supplementation of L-car did not have significant effect on percentage of abdominal fat (Table 15). These finding are in accordance with Rabie *et al.* (1997), Daskiran and Teeter (2001), Lien and Horng (2001), Haghighi Khoshkhoo *et al.,* (2006). However few reporters (Rabie *et al.* 1998; Xu *et al.*

2003; Rezaei *et al.* 2007) indicated significant reduction in abdominal fat by dietary L-car supplementation. The variation might be due to the proportion of UFA: SFA in the diet which is known to effect the abdominal fat deposition irrespective of carnitine supplementation.

There was a significant interaction between fat source and L-car on abdominal fat deposition. There was significant ($P<0.05$) reduction in abdominal fat when carnitine was added to TAL based diet whereas a reverse trend was observed for CSBO. Under normal process, in mammals, fats undergo β-oxidation by the enzyme system in both mitochondria and peroxisomes. Fatty acids shorter than 16 carbons are oxidized at the same rate by both systems independent of carnitine. Peroxisomal β-oxidation was known to be stimulated, by higher concentration of MUFA (Halvorsen *et al.*, 2001) and higher dietary fat, but they do not yield ATP. Thus energy efficiency by this mechanism is poorer and also increases serum triglycerides with subsequent increase in abdominal fat deposition. Rather L-car stimulates mitochondrial β-oxidation of fatty acids by facilitating their transport across the mitochondrial cell membrane.

In the present experiment, the TAL fed birds deposited more fat compared to those fed CSBO (Table 15), perhaps due to higher concentration of MUFA present in TAL (41.37%) compared to CSBO (25.44%), Table 11. Supplementation of carnitine to TAL based diet might have facilitated transportation of the MUFA for their subsequent oxidation in mitochondria and resulted in reduced fat deposition in abdominal area (Table 15). Reduction of abdominal fat in birds fed TAL with carnitine might have contributed partly to the reduction in weight gain compared to those fed CSBO.

5.1.3.3 Moisture Percentage of Liver, Light and Dark Muscles

Moisture percentage of liver and dark muscle are significantly ($P<0.05$) influenced by the fat source. Moisture percentage of liver reduced significantly by feeding CSBO than those fed TAL and a reverse trend was seen in dark muscle (Table 16). However, the moisture percentage of light muscle was not significantly ($P>0.05$) influenced by the fat source. Similar finding was reported by Özdoğan and Akşit (2003), who stated that the moisture content of dark muscle was significantly ($p<0.05$) higher in broilers fed on diet containing soybean oil compared to broiler fed with tallow, whereas moisture content of light muscle was not influenced by the fat source.

Effect of carnitine supplementation on moisture percentage of liver was significantly ($P<0.05$) increased by adding 100 mg/kg L-car whereas a reverse trend was seen in moisture percentage of dark muscle. However moisture percentage of light muscle was not significantly ($P>0.05$) influenced by L-car supplementation.

Interaction between fat source and L-car was significant ($P<0.05$) for moisture percentage of liver, light and dark muscles. The data suggests that L-car supplementation significantly ($P<0.05$) increased moisture percentage of liver and light muscle for CSBO and TAL fed birds, respectively. Whereas moisture percentage of dark muscle was significantly reduced in CSBO but not for TAL fed birds. The interaction data thus indicated that the effect of carnitine supplementation depends on fat source, tissue.

5.1.3.4 Fat percentage of Liver, Light and Dark Muscle

The fat percentage of liver was significantly ($P<0.05$) high for CSBO than TAL (Table 16). Implying better absorption of soybean oil or it may be due to enhanced hepatic lipogenesis as reported by Crespo and Esteve-Garcia (2002c).

Fat percentage of light muscle was significantly (P<0.05) lower for CSBO fed group than TAL fed birds (Table 14) whereas fat percentage of dark muscle was not significantly influenced by fat source. This lower fat deposition in light muscle of birds fed with CSBO might be attributed to enhance β-oxidation of fatty acids in light muscle. Similarly Sanz *et al.* (2000a) reported that activity of enzyme carnitine palmitoyltransferase-I was more in birds fed unsaturated fat (sunflower oil) than those fed saturated fat (TAL) in muscle implying greater β-oxidation of fatty acids resulting in lower fat deposition. Few authors (Sanz *et al*., 1999; Newman *et al.*, 2002) also indicated that fat content of light muscle was significantly higher in TAL fed birds compared to PUFA fed birds. However, Crespo and Esteve-Garcia (2001) noticed dietary fat source did not have any significant effect on light muscle fat. Similarly, Özdoğan and Akşit (2003) found that fat content in dark and light muscles did not differ significantly in birds fed on soybean oil or TAL.

The effect of carnitine supplementation on fat percentage of liver, light and dark muscles was significantly (P<0.05) higher at 100 mg/kg L-car dietary level.

Interaction effect was not significant (P>0.05) for liver fat percentage, whereas interaction effect was significant (P<0.05) for fat percentage of light and dark muscles. In the present experiment, the CSBO fed birds deposited less fat in light and dark muscles which might be due to higher concentration of polyunsaturated fatty acids present in CSBO (58.83%) when compared to TAL (1.98%). Supplementation of L-car to CSBO based diet resulted in increased fat percentage of light and dark muscles. Similarly Xu *et al.* (2003) reported that the breast muscle percentage and fat content in breast muscle was significantly increased by adding 50 or 75 or 100 mg/kg L-car when corn oil was used as fat

source. They concluded that higher dosage (≥ 50 mg/kg) of dietary L-car induced partial inhibition of malonyl-CoA enzyme in the muscle cell which in turn might have reduced the activity of carnitine palmitoyltransferase -I in breast muscle. As a result reduced activity of the enzyme might have reduced the β-oxidation of fatty acids and thus enhanced the fat accumulation in the intramuscular tissue. Contradictory to our finding, Rezaei *et al.* (2007) reported reduced fat content in breast muscle by adding 250 mg/kg L-car to isocaloric diet with three levels of soybean oil (1, 3 and 5%) and interaction effect was significant only at 3% level of oil inclusion, indicating significant reduction of breast fat by adding L-car to 3% soybean oil diets. Thus it can be concluded that effect of carnitine depends upon the level of fat inclusion, fatty acid composition of supplemental fats and also level of carnitine supplementation.

5.1.4 Serum lipid profile

5.1.4.1 Serum Triglycerides

The effect of fat source on the concentration of serum triglycerides was significantly ($P<0.05$) low for TAL than CSBO at 3 hr fasting (Table 15). The difference in the levels of triglycerides can be attributed to the difference in the digestibility and absorption of fatty acids in poultry. Doreau and Chilliard (1997) reported that the digestibility of fatty acids decreases with increase in the chain length of saturated fatty acids from 14 to 18 carbon (C) atoms and increase with unsaturation for C 18 FA: 60, 86 and 83% for 0, 1 and 2 double bonds with TAL. This is due to saturated fatty acid having less ability to form micelles than unsaturated fatty acids (Wiseman, 2003 and Stahly, 1984). They reported higher digestibility for TAL when UFA: SFA ratio is higher than 1.5, indicating there was

synergism between SFA and UFA. Thus in the present experiment, lower and higher concentration of serum triglycerides at 3 hrs fasting for TAL and soy oil may be due to lower and higher ratios of UFA: SFA (0.76 and 5.51) respectively. However, opposite tend was observed by Sanz *et al.* (2000a), who reported that significantly ($P<0.05$) lower plasma triglyceride concentration after 2.5 hrs in broilers fed sunflower diet than TAL and suggested that it might be due to higher postprandial rate of fat uptake from bloodstream to tissues and thus better clearance of triglycerides from blood. Similarly, Meijer and Beynen (1988) reported, increase in plasma triglyceride and cholesterol concentrations in rats fed with saturated fats (coconut fat) compared to those fed polyunsaturated fats (corn oil). They further observed a lack of significant influence of supplementation of carnitine (1% w/w) on those two parameters.

In case of 12 hrs fasting, significantly ($P<0.05$) lower concentrations of triglyceride were observed for crude soybean enriched diets, which may be due to increased lipoprotein activity in the mitochondria of muscle resulting in the enhanced rate of fatty acid oxidation and depression of serum triglycerides level (Shimomura *et al.,* 1990). This higher level of serum triglycerides in TAL fed birds reflected in higher abdominal fat deposition. Whereas Newman *et al*. (2002), Özdoğan and Akşit (2003) and Alparslan and Özdoğan (2006) found dietary fat source and level of inclusion of dietary fat had no significant effect on serum triglyceride levels.

Supplementing 100 mg/kg L-car resulted in the reduction of serum triglycerides. These findings are in accordance with Xu *et al.,* (2003) and Rezaei *et al.,* (2007).

5.1.4.1 Serum Cholesterol

Serum cholesterol was higher in CSBO compared to those fed TAL and is in accordance with findings of the previous report (Özdoğan and Akşit 2003). Significantly ($P<0.05$) lower serum cholesterol concentrations in tallow fed diet (Table 17), may be attributed to higher content of oleic acid (18:1) in tallow (39.05%) compared to CSBO (25.33%), (Table 9). Similarly few authors (Grundy, 1986; Chang and Huang, 1998) indicated that consumption of diet supplemented with fat rich in oleic acid (18:1) was associated with reduced cholesterol, arteriosclerosis, and heart disease. High oleic acid also increases oxidative stability of fats or oil. Whereas Crespo and Esteve-Garcia (2001), reported that feeding polyunsaturated fatty acids resulted in reduction of cholesterol which is highly correlated with abdominal fat deposition.

L-car supplementation significantly ($P<0.05$) reduced the serum cholesterol in TAL and CSBO fed groups. These results are in agreement with Rezaei *et al.* (2007).

Serum cholesterol was inversely proportional to abdominal fat deposition and when carnitine was added, abdominal fat deposition was directly proportional to serum cholesterol.

PART II

Effect of Unsaturated to Saturated fatty acid ratio with or without L-carnitine

5.2.1Performance Parameters

5.2.1.1 Body Weight Gain

The body weight gain of broilers was significantly ($P<0.05$) influenced by UFA: SFA ratio during starter, finisher and overall period but there was no significant trend in weight gain (Table 18). However, body weight gain was significantly high and low at 70:30 and 75:25 ratios of UFA: SFA, respectively during all the phases recorded. Navidshad *et al.* (2006) also reported that feeding diets with UFA: SFA ratio 6.5 adversely affected weight gain when compared to other ratios of UFA: SFA (2, 3.5 and 5). Similarly, Wongsuthavas *et al.* (2007a) found that the average daily weight gain of broilers was not systematically influenced by feeding with three levels (3, 6 and 9%) of soybean- tallow blends, composing of different ratio of SFA: UFA ratio (1:1, 1:2, 1:3, 1:4 and 1:5). Significantly higher weight gain was observed at the lowest ratio of SFA: UFA at 3 and 9% oil inclusion.

The present experimental data suggested that the best synergism between unsaturated and saturated fatty acid at 70:30 ratio and further increase in the ratio did not show any advantage. These findings are contradicted with that of Ketels and De Groote (1989), who reported that, the best digestibility of fats at UFA: SFA ratio of 4 and further increasing ratios did not reduce their digestibility. The reported variation might be due to the quantity of supplemental fat used in the diet. Highest synergism between saturated and unsaturated fats was reported by Lewis, (1989) at less than 3% supplemental fat.

Supplementation of 100 mg/kg L-car significantly (P<0.05) reduced body weight gain during starter, finisher and overall period of the experiment. Whereas, Lien and Horng (2001) reported no significant (P>0.05) reduction in weight gain in broilers fed 160 mg/kg L-car (1789 vs 1860g for without carnitine respectively). At higher environmental temperature supplementing L-car or L-car and ascorbic acid increased body weight gain (Celik and Ozturkcan, 2003) whereas a reverse trend was observed under thermo-neutral condition.

5.2.1.2 Feed Consumption

Feed intake was significantly (P<0.05) high at 70:30 ratio during starter and finisher period. Cumulative feed intake at 6 weeks of age increased with increase in ratios from 60:40 to 70:30 and thereafter sudden drop in feed intake was observed (Table 19). These results are in agreement with Navidsha *et al.* (2006), who reported sudden fall in feed intake at 6.5 ratio of UFA: SFA than 2.5, 3.5 and 5 during grower (77.58 vs 80.96, 81.49 and 80.56 g/day) and finisher phases (89.22 vs 92.29, 91.88 and 92.47 g/day). Conversely, Wongsuthavas *et al.*, (2007a) reported absence of significant influence of SFA: UFA ratio on feed intake.

Effect of carnitine on feed intake was significantly (P<0.05) reduced in broilers fed diets supplemented with carnitine during starter phase, whereas during finisher and overall period, feed intake was not affected with carnitine supplementation.

The interaction between carnitine supplementation and UFA: SFA ratio of supplemental fats was significant (P<0.05) for feed intake during starter, finisher and overall period. During starter phase L-car supplementation to UFA: SFA ratio significantly reduced feed intake at all the ratios except at 70:30, where the

carnitine supplementation increased feed intake. Similarly, the feed intake increased significantly during overall period with L-car supplementation at 60:40 ratio of UFA: SFA diet.

5.2.1.3 Feed per Gain

The effect of UFA: SFA ratio was significantly ($P<0.05$) better for 60:40 ratio during finisher and overall period of the experiment and during starter period 75:25 ratio has significantly better FCR when compared to the other ratios (Table 20). Similarly Navidshad *et al.* (2006) reported lowest FCR in birds fed with 3.5 UFA: SFA ratio when compared with 5 and 6.5 ratio of UFA: SFA. Thus the present data suggested that as the unsaturation of supplemental fat increased feed efficiency decreased. These findings are contradictory to Wongsuthavas *et al.* (2007a), who reported lowest FCR at higher inclusion of unsaturated fats at the expense of saturated fats.

Supplementing L-car significantly ($P<0.05$) reduced the performance during starter and finisher periods (Table 20). Khadem *et al.* (2006) also reported that supplementing L-car at 50 mg/kg had no significant effect on FCR. Similarly, other authors (Xu *et al.*, 2003; Baker and Sell, 1994) also indicated that the dosage of carnitine did not have significant on FCR.

The interaction effect between carnitine and UFA: SFA ratio on feed per gain was significant ($P<0.05$) during starter phase (Table 20). The interaction data suggested that supplementing 100 mg/kg L-car to diet containing 75:25 UFA: SFA ratio had significantly better feed per gain, whereas at 70:30 ratio it resulted in poor FCR and at other ratios it remained unaffected. The interaction effect on feed

per gain was not significant (P>0.05) during finisher (28-42 days) and overall period (0-42 days).

5.2.2 Carcass Parameters

5.2.2.1 Carcass Yields

The ratio of unsaturated to saturated fatty acids and L-car supplementation alone or interaction between them did not have significant (p>0.05) effect on slaughter variables studied (Table 21) except the abdominal fat percentage. However, significant (p<0.01) increase in dressing percentage as the ratio of unsaturated to saturated fatty acid increased from 2 to 6 was reported in the literature (Wu *et al.*, 1994) .

5.2.2.2 Abdominal Fat Percentage

In the present study except at 70:30 ratio, abdominal fat percentage decreased with increase in the ratio of UFA: SFA (Table 21). These findings are in accordance with Wongsuthavas *et al.* (2007a and 2007b) and Nosrati *et al.* 2006 (at 28day of age) who reported a significant decrease in the abdominal fat content with increase in unsaturation in the diet, implying that unsaturated fats inhibit *de novo* fatty acid synthesis and subsequent reduction in abdominal fat deposition.

Dietary supplementation of L-car did not show any significant (P>0.05) effect on the percentage of abdominal fat (Table 21). This finding contradicts with the finding of Khadem *et al.* (2006) who reported significant (P<0.05) reduction in fat pad percentage with L-car (50 mg/kg) supplementation in broiler diet.

The interaction between L-car and ratio of UFA: SFA of supplemental fat was significant (P<0.05) for abdominal fat deposition. The interaction data

suggested that least amount of abdominal fat deposition was observed in broiler fed with 75:25 followed by 70:30 ratio with 100 mg/kg L-car in the diets, indicating that the supplementation of L-car was efficient at higher ratio of unsaturated to saturated fatty acid in reducing abdominal fat deposition.

5.2.2.3 Moisture Percentage of Liver, Light and Dark Muscles

The moisture percentage of liver, light and dark muscles was significantly ($P<0.05$) influenced by the ratio of UFA: SFA and L-car. The moisture content of liver showed a decreased trend as the unsaturation of supplemental fat increased, however there was no consistent pattern in moisture percentage of dark and light muscles.

Interaction effect was significant ($P<0.05$) for moisture content of three tissues. The data suggested that at higher ratio of UFA: SFA, supplementing L-car resulted in increase in moisture content of liver and dark muscle and correspondingly fat content in the liver might have reduced.

The addition of carnitine to diets containing different UFA: SFA ratio resulted in significant reduction in the moisture content of light muscle at all the ratios of UFA: SFA except at 75:25 ratio, where the moisture content in light muscle increased with carnitine supplementation.

5.2.2.4 Fat percentage of Liver, Light and Dark Muscle

Effect of ratio of UFA: SFA on liver fat percentage was significantly ($P<0.05$) lower at 75:25 ratio of UFA: SFA compared to 60:40, 65:35 and 70:30 ratios of UFA: SFA. Carnitine supplementation significantly ($P<0.05$) reduced the liver fat content (Table 22). This reduction of liver fat might be due to increased fat

catabolism with carnitine supplementation. There was significant reduction in liver fat percentage at 70:30 ratio with 100 mg/kg L-car compared to those fed the same ratio of UFA: SFA without carnitine supplementation. Carlson *et al.* (2006) also reported decreased liver fat concentration with carnitine supplementation and they attributed the liver fat reduction to increased *in vitro* fatty acid oxidation which reduced the proportion of fatty acids converted to triglycerides in the liver. Similarly, in the experiment conducted with rats, Tao *et al.* (1981) reported that high dose of carnitine supplementation in the total parental nutrition regimen significantly reduced liver fat content and concluded that the reduction is due to increased fat oxidation in liver.

There was significant effect ($P<0.05$) of UFA: SFA ratio on fat deposition in light and dark muscles but no specific trend was found. However significantly lowest and highest fat deposition was observed at 70:30 and 75:25 ratio in both the muscles. Wongsuthavas *et al.* (2007a) reported that as the ratio of SFA: UFA decreases from 1:2 to 1:5, there was a significant reduction in the number of fat cells in the breast muscle, by regulating transcription factors which are involved in adipocyte development.

Effect of carnitine supplementation was significantly ($P<0.05$) low and high for fat content of light and dark muscles respectively. This might be due to the existence of difference in redistribution of lipids with carnitine supplementation in the various tissues.

Effect of interaction was significant ($P<0.05$) for both light and dark muscle fat percentage. However, lowest fat deposition in light muscle fat was observed at 60:40 without carnitine followed by 70:30 (with and without carnitine) and similar trend was found for dark muscle fat with minor difference.

5.2.3 Serum lipid profile

5.2.3.1 Serum Triglycerides

The serum triglycerides levels were significantly ($p<0.001$) effected by the ratio of UFA: SFA (Table 23) at 3 and 12 hr fasting but there was no dose dependent reduction. The results are in agreement with Nosrati *et al.* (2006) and Wongsuthvas *et al.* (2007b) who found a significant ($P<0.05$) decrease in serum triglyceride concentration with increase in unsaturation of supplemental fats. In the present experiment lower concentration of triglycerides was found at 70:30 ratio but deposition of abdominal fat was low at 65:35 and 75:25 without and with carnitine, respectively followed by 70:30 with carnitine. This implies that, there was no clear relation between serum triglycerides and abdominal fat deposition.

The serum triglyceride concentration reduced significantly ($P<0.05$) with L-car supplementation (Table 23). It could be due to supplementation of L-car, which might have increased the rate of fatty acid transportation across the mitochondrial membrane in broilers and thus resulting in lower concentration of serum nonesterified fatty acid and triacylglycerols.

The supplementation of L-car significantly ($P<0.05$) reduced the serum triglyceride concentration at all ratios of UFA: SFA at 3 hrs fasting but at 12 hrs fasting, such reduction was observed at 60:40 and 75:25 ratio but not at other ratios.

5.2.3.1 Serum Cholesterol

Variation in the ratios of UFA: SFA was significantly ($P<0.05$) influenced the serum cholesterol levels. As the ratio of UFA: SFA increased, the concentration of serum cholesterol decreased up to 70:30 and thereafter the serum

cholesterol increased significantly. Nosrati *et al.* (2006) also reported a significant reduction in the serum cholesterol concentration with increase in the unsaturation of supplemental fat during starter period and lack of such effects during finisher period was reported by Wongsuthavas *et* al. (2007b).

Highest concentration of cholesterol was recorded at 75:25 ratio followed by 65:35 ratio and with carnitine supplementation maximum concentration of cholesterol was observed at 60:40 followed by 75:25 ratio.

In this experiment with respective ratios of UFA: SFA, the serum cholesterol levels were negatively correlated with abdominal fat percentage. The abdominal fat deposition was significantly lower at 65:35 and 75:35 ratio without carnitine supplementation (1.71 and 1.80%), in which the cholesterol levels were recorded to be high, viz., 181.65 and 198.33 mg/dl respectively. Thus serum cholesterol estimation is the best indicator for abdominal fat content.

CHAPTER VI

SUMMARY AND CONCLUSIONS

In the broiler ration formulation fats or oils are used invariably for meeting up energy demand of present superior germ plasm. Animal fats are considered to contain higher energy but their metabolizable energy was low because of the imbalance between unsaturated and saturated fatty acid. Thus to enhance the energy utilization of birds fed with animal fats, they should be suitably blended with vegetable oils which are rich source of unsaturated fatty acids.

Even though heavier body weight gains were observed by lipid saturation, it is undesirable because heavier body weight is attributed to higher content of abdominal fat and oily carcasses, which are undesirable to the consumer. Supplementation of oils/fats become essential in the broiler diet to realize the maximum genetic potential of the bird. The composition of supplemental fat has direct impact on quantity and composition of carcass fat. It is important to feed the bird with appropriate ratio of UFA: SFA in the supplemental fat.

Present experiment was carried out with the following assumptions

- Better performance of broilers can be achieved by feeding blend of animal and vegetable oils rather than feeding either of them alone. Assuming that there might be a better synergism between saturated and unsaturated fatty acids of blends.
- L-carnitine was added with an assumption that it promotes oxidation of fatty acid resulting in decreased availability of long chain fatty acids for the esterification to triacylglycerols therefore reducing the serum triglycerides and cholesterol. Ultimately resulting in the lesser availability of triglycerides to get deposited as fat in muscle tissues.
- Carnitine also lowers abdominal fat deposition by decreasing the activity of enzyme lipoprotein lipase which plays a major role in the subcutaneous fat deposition.

- ❖ Other assumption was that L-carnitine improves the performance of broiler by enhancing the energy utilization of long chain fatty acids preferentially by facilitating their transfer across the inner mitochondria for ß oxidation rather than peroxisomal oxidation.

The effect of fat source and various ratios of UFA: SFA (60:40, 65:35, 70:30 and 75:25) with or without L-car was studied on the growth performance, carcass yield and serum lipid profile of male broiler chick from day one to six week of age. The fatty acid profile of supplemental fat and oil became prerequisite for formulating different ratio of UFA: SFA (60:40, 65:35, 70:30 and 75:25) and energy contributed by these ratios was kept constant.

The growth trial was conducted in a factorial design with two levels of L-carnitine (6x2) based upon completely randomized design, consisting of 96 groups with 5 male broilers per group. The starter and finisher diets formulated were isocaloric and isonitrogenous and fed up to four weeks and 5^{th} and 6^{th} week respectively. As the experimental data was exhaustive it has been made into two parts for convenience of discussion. First part deals with fat sources and second part deals with ratio of UFA: SFA with or without carnitine supplementation.

The effect of fat source on body weight gain of broiler was significantly ($P<0.05$) higher for crude soybean oil than tallow during starter and overall period. Carnitine supplementation resulted in significantly ($P<0.05$) higher body weight gain during finisher period. The interaction was significant ($P<0.05$) for starter, finisher and overall periods which was positively influenced by supplemented L-car in broilers fed CSBO and negatively in those fed TAL diets. The effect of ratio of UFA: SFA, supplemental carnitine and their combination was significant ($P<0.05$) during starter, finisher and overall periods. 70:30 ratio showed

significantly higher weight gain and upon adding carnitine there was significant reduction of weight gain from 65:35 to 75:25 ratio.

The effect of fat source on feed intake was significantly (P<0.05) low for tallow diet during starter and effect of carnitine was significantly (P<0.05) low during starter and overall period. Interaction effect was significant (P<0.05) during finisher and overall period. The feed intake was significantly (P<0.05) high for 70:30 ratio of UFA: SFA during starter, finisher and overall periods. And effect of carnitine supplementation was significantly (P<0.05) low for starter period.

FCR was significantly (P<0.05) better for CSBO. Fat source with L-car significantly (P<0.05) improved FCR during overall period (0-42 days) of age. FCR was improved by dietary L-car supplementation during starter, finisher and overall periods. Interaction effect was significant (P<0.05) during starter and overall periods. Effect of UFA: SFA ratio and carnitine was significant (P<0.05) during starter, finisher and overall periods. FCR was significantly (P<0.05) better for 60:40 ratio during finisher and overall periods and for diets without L-car. Interaction effect was seen only for starter period.

The dressing yield, R to C and breast yield along with skin and giblet percentage were not influenced by various dietary treatments. But abdominal fat percentage was significantly (P<0.05) influenced by the interaction between fat source and carnitine but not with fat source or carnitine alone. Significantly (P<0.05) lowest abdominal fat content was observed for CSBO without carnitine and addition of carnitine reduced significantly (P<0.05) abdominal fat percentage in the case of TAL diet but not with CSBO diets. The abdominal fat percentage at the ratio of UFA: SFA was significantly (P<0.05) low for 75:25 and 65:35 followed by 70:30 ratio. Abdominal fat percentage was not influenced by carnitine

for UFA: SFA ratio. The interaction effect on fat deposition was significantly ($P<0.05$) low by adding carnitine at 70:30 ratio, but was not altered much at the remaining ratios.

Moisture content of liver and dark muscle was significantly ($P<0.05$) high for TAL and CSBO respectively, whereas moisture content of light muscle was not influenced by the fat source. L-car supplementation has significantly ($P<0.05$) increased liver moisture percentage and decreased significantly dark muscle moisture percentage. Significantly ($P<0.05$) higher moisture content of light and dark muscles was observed at 65:35, 75:25 and 70:30 ratio respectively. Carnitine supplementation to UFA: SFA diets significantly ($P<0.05$) increased moisture content of dark muscle, whereas in light muscle it resulted in significant ($P<0.05$) reduction of moisture percentage. The interaction effect was significant for all the three.

Liver fat percentage was significantly ($P<0.05$) influenced by the fat source, carnitine and in combination. Significantly lower fat content was observed for tallow diet and diets without carnitine. Liver fat percentage was significantly ($P<0.05$) influenced by UFA: SFA ratio, carnitine and or combination. Significantly ($P<0.05$) highest fat percentage was found with 70:30 ratio and upon addition of carnitine to this ratio resulted in significant reduction of liver fat percentage.

The fat percentage of light muscle along with skin was significantly ($P<0.05$) influenced by the fat source alone and the combination of fat and carnitine. Significantly ($P<0.05$) lowest fat percentage was found for crude soybean oil and addition of carnitine at 100 mg/kg resulted in significant reduction of fat percentage for tallow diet but not for soybean oil. UFA: SFA ratio, carnitine

and in combination had significant ($P<0.05$) influence on light muscle fat percentage. Significantly ($P<0.05$) lowest percentage was observed at 70:30 and 60:40 ratios and overall effect of carnitine was significantly low at 100 mg/kg L-car.

The fat percentage of dark muscle was not significantly ($P>0.05$) influenced by the fat source whereas L-car supplementation and their combination had significant ($P<0.05$) effect on dark muscle fat content. Lowest fat percentage was observed for birds fed on CSBO without L-car supplementation. The fat percentage for dark muscle with skin was significantly influenced by the UFA: SFA ratio, carnitine alone and or the combination. The effect of UFA: SFA ratio and carnitine was significantly ($P<0.05$) low and high for 70:30 ratio and with L-car supplementation respectively.

Serum triglycerides concentration was significantly ($P<0.05$) influenced by the fat source, carnitine and or in combination. Significantly ($P<0.05$) lower concentration was observed for tallow and crude soybean oil for 3 and 12 hrs fasting respectively. However fasting serum triglyceride concentration was significantly ($P<0.05$) low at 100 mg/kg L-carnitine. The effect of UFA: SFA ratio, carnitine and or in combination was significant ($P<0.05$) for fasting serum triglyceride. As unsaturation increased the serum triglyceride concentration subsequently decreased and lowest concentrations were observed at 75:25 ratio and 70:30 ratio for 3 and 12 hrs fasting respectively. L-carnitine significantly ($P<0.05$) reduced fasting triglyceride levels.

Serum cholesterol concentration was significantly ($P<0.05$) influenced by fat source and carnitine. Significantly ($P<0.05$) lowest concentration was noticed for tallow diets and 100 mg/kg L-car supplementation. But interaction effect was

not significant. The effect of UFA: SFA ratio, carnitine alone and or in combination on serum cholesterol was significant ($P<0.05$). Within the ratios significantly ($P<0.05$) lowest concentration was noticed at 70:30 with or without L-car supplementation.

CONCLUSIONS

The following conclusions are drawn from the results of this experiment.

- From discussion I it was evident that the performance of broilers in terms of weight gain, FCR and percentage of carcass yield was similar in broilers fed TAL and CSBO without carnitine supplementation. However fat content in abdominal region, light and dark muscle was lower for crude soybean oil than saturated fat tallow.

- Among the ratios between UFA: SFA without carnitine supplementation, optimum growth rate was obtained at 70:30 but when FCR and carcass quality were considered 60:40 ratio performed better than 70:30 ratio. However percentage of carcass yield was unaffected. Abdominal fat accumulation was low at 65:35 and 75:25 UFA: SFA ratios.

- From results I carnitine supplementation improved performance (body weight gain and FCR) in CSBO fed birds when compared to birds fed tallow diet with or without carnitine supplementation and CSBO without carnitine.

- Supplementing carnitine in tallow based diets resulted in lean meat production. The same is not true for crude soybean oil, indicating long chain-monounsaturated fatty acids of tallow are better utilized by supplementing carnitine than oil which was evident by serum triglyceride levels at 12 hrs fasting.

- From results II growth performance was not influenced by carnitine supplementation. However carcass quality was better at 70:30 ratio with

carnitine in terms of fat percentage of abdominal, light and dark muscles when compared with other ratios supplemented with carnitine.

- However carnitine supplementation reduced triglycerides and cholesterol in serum.

- Based on the data, it can be concluded that economic traits (body weight gain and FCR) and carcass quality traits (abdominal, light and dark muscle fat percentage) were better for CSBO with carnitine and CSBO without carnitine respectively. The better body weight gain and FCR were observed at the optimum ratios of 70:30 and 60:40 of UFA: SFA without carnitine respectively. However, lean meat was obtained at 70:30 ratio with carnitine.

CHAPTER VII
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