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COMPARATIVE EFFECTS OF DIFFERENT DIETARY OMEGA- FATTY ACIDS ON GROWTH PERFORMANCE AND SERUM LIPID COMPOSITION IN RATS

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ABSTRACT

Comparitive effects of different dietary omega fatty acids on growth performance and serum lipids composition in rats were investigated using male weaning albino rats (120 rats) fed for two weeks a semipurified diet (basal diet) before being fed the experimental diets. The rats were randomly divided into eight groups of 15 rats each. Each group of rats was fed a single experimental dietary oil or an oils mixture as the sole source of fat for three months. Growth performance; composition of serum lipoprotein; and fatty acids composition of serums of rats were investigated. Results revealed that the growth performance of rats was improved when rats fed on flaxseed oil (FO) high in (*omega*-3) fatty acids followed by corn oil (CO) high in (*omega*-6) fatty acids; oilve oil (OO) high in (*omega*-9) fatty acids; and finally palm oil (PO) high in saturated fatty acids, respectively. Serum lipids of rats fed the dietary PO showed the highest total lipids (TL), while those fed (FO) showed the lowest. Total cholesterol (TC) contents increased as the dietary oils increased in the degree of saturation. Rats fed PO showed the highest TC content. However, data showed no clear differences in TC among rats fed dietary FO; CO; and OO. Nevertheless, they were less than those found with dietary PO. CO was less effective, to some extent, when incoperated with OO than incoperated of FO with OO . Feeding rats on the dietary mixture of FO/CO/OO (1:1:1) further decreased the TC content. High denesity lipoprotein-cholesterol (HDL-C) showed the same trend as for triglycerides TG and TC. Feeding rats FO showed the highest HDL-C representing 52.57% of the TC content. Dietary PO (saturated), on the other hand, showed the lowest HDL-C representing 13.39% of the TC content. Data revealed that the fatty acids composition of the serum lipids were markedly affected according to the type of dietary oil used.

Keywords: Omega (n)-fatty acids, growth performance, serum lipid, fatty acids composition, flaxseed oil, corn oil, oilve oil, palm oil, total cholesterol, high denesity lipoprotein-cholesterol, low denesity lipoprotein-cholesterol.

INTRODUCTION

Several species of marine fish offer a rich dietary source of omega-3 (*n*-3) fatty acids especially eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) but these acids are not regularly included in the Egyptian diet. For majority of the population, the alternative dietary source of long chain *n*-3 fatty acids might be their precursor, α- linolenic acid (ALA; 18:3 *n*-3). ALA is found in many foods including flaxseed oil, walnuts and leafy vegetables. Previous reports suggested that increased intake of ALA similarly to be intake of EPA and DHA, may have beneficial effects in health and in control of chronic diseases (Kurowska *et al.,* 2003 and Moreira *et al.*,2010). lipoproteins, diet is a cornerstone in the prevention and treatment of such chronic diseases. In the modern diet the three saturated fatty acids (SFA's), such as lauric, myristic and palmitic acids comprise 60-70 % of all SFA and

responsible for the cholesterol raising effect of saturated fat. A common strategy is to reduce (SFA) in the diet and replace it with polyunsaturated fatty acids (PUFA'S), monounsaturated fatty acids (MUFA) or complex carbohydrate in order to retain a suitable energy balance. The major MUFA in the diet is oleic acid 18:1 (*n*-9) which is the predominant acid in olive oil. Olive oil is the major component in the mediterranean diet, to which it contributes more than 15% of energy. Studies have shown that blood cholesterol levels and the incidence of chronary heart diseases (CHD) are much lower in mediterraneans than other countries (Albert *et al.,* 2002 and Gleissman *et al.,* 2010). The major dietary of PUFA is linoleic (*n*-6) which is predominate in vegetable oils (e.g., corn and sunflower oils), when substituted for SFA, this markedly reduces the total cholesterol. Other PUFA include, α- linolenic acid (*n*-3) (e.g., flaxseed oil) and EPA and DHA contained in marine fish. There are currently two possible models to explain the alterations in the serum lipid profile that occur with *n*-3 fatty acids. The first model suggests that *omega*-3 fatty acids, may divert hepatic fatty acids to β-oxidation (Wang *et al.,* 1994). As consequence, there may be less TG synthesis, an increase in apoprotein β-degradation and a reduction in the size and number of secreted VLDL particles. An alternative model suggests that the decreases in serum TG reduce the amount of substrate available for hydrolysis by lipoprotein lipase. As a consequence of the reduced substrate concentration, the amount of lipolysis product, nonesterfied fatty acids (NEFA) are also reduced. Data of Pownall *et al.* (1999) and Harris *et al.*(2008) suggested that elevated TG concentration and cholesterol ester transfer activity (CETA) are the two major determinants of the altered HDL and LDL structure found in hypertriglyceridemia. Treatment with *omega*-3 fatty acids appeared to change the lipid profile of individuals with elevated TG to one that may be less atherogenic by changing LDL structure lowering serum CETA; serum TG and VLDL; and increasing serum HDL. *Omega*-3 fatty acids increases the cholesterol ester (CE) content of HDL in a predictable way and may make the HDL more resistance to the hepatic lipase-mediated conversion to smaller, more dense HDL. Thus in hypertriglyceridemic patients, *n*-3 fatty acids reduce serum TG concentration and improve other mechanically related lipid risk factors. The aim of this study was to investigate the comparative effects of different omega-fatty acids on growth performance and serum lipid composition in rats.

MATERIALS AND METHODS

Materials:

Oils

Fresh cold pressed flaxseed oil, (FO) 5 kg was obtained from a commercial Flaxseed Press Mill, EL Mehalla EL Kobra, Gharbia governorate, Egypt. Corn oil, (CO) 5 kg was obtained from a local market, Alexandria, Egypt and Palm oil, (PO) 5 kg was obtained from Savola Sine, Suez, Egypt. Fresh olive oil, (OO) 5 kg was obtained from the Gianclis Kroom Co. Egypt.

Animals and diets

Male weaning albino rats (120 rats), aging 45 days with an average weight of 30-45 g were obtained from the Home Economics Department, Faculty of Agriculture, Alexandria University. The animals were housed in a well-ventilated suspended stainless steel mesh cages and kept in an environmentally controlled room at 22+ 2°C, and relative humidity of 50+ 10%, with an automatic lighting from 07.00 to 18.00 hours. Water and food were provided *ad libtium.* All animals were adapted to their surrounding for two weeks and fed a semipurified diet (basal diet, Table 1) containing 10% protein (casine), 10% oil, 1% vitamins mixture, 4% mineral mixture, 5% cellulose and carbohydrates (starch) were added to complete the diet before being fed the experimental diets according to (AOAC, 2000). The rats were randomly divided into eight groups of 15 rats. Each group of rats was fed one of the following experimental dietary oil as the sole source of fat for three months. The basal diet was supplemented with one of of the following oil: flaxseed oil (FO) as the richest α -linolenic acid (18:3, *n*-3); corn oil (CO) as the richest linoleic acid (18:2, *n*-6); and palm oil (PO) as the richest saturated oil (high in palmitic acid 16: 0) and was considered as the control dietary oil. FO was also mixed with OO in a ratio of (1:1 v/v) and assigned as the dietary (FO/OO). FO was also mixed with CO at the same ratio (1:1 v/v) and assigned as the dietary (FO/CO). CO was mixed with OO at (1:1 v/v) and assigned as the dietary (CO/OO). Mixture of FO; CO; and OO were also mixed together at ratio of (1:1:1 v/v/v) and assigned as the dietary (FO/CO/OO).

Ingredients	

Table1

Fatty acids composition of oils

Fatty acids methyl esters (FAME) of oils were performed according to the procedure of Radwan (1978). Analysis of FAME was carried out using a gas chromatography (HP 6890; Hewlett Packared Co., Wilmington, DE, USA). AHP-5 (5 % diphenyl 95% dimethyl polysiloxane) capillary column (30 m x 0.32 mm x 0.25 nm) and flame ionization detector were used. Injector and detector temperatures were 220 and 250 °C, respectively. N_2 was employed as the carrier gas at a flow rate of 0.8 ml/ min.

Growth performance

Feed intake: Feed intake was recorded throughout the experiment period, and the means of daily feed intake was determined.

Body weight: Body weight of each rat was recorded weekly throughout the experimental period. The animals were weighed early in the morning before being access to feed or water till the end of the experiment.

% weight gain = (final weight – initial weight) x 100/initial weight. Feed conversion = feed consumption/body weight gain and Feed efficiency = weight gain x 100/feed intake were caculated.

Serum lipids composition

The concentrations of (TG), (TC) and (HDL-cholesterol) and (LDL-cholesterol) in serum were determined calorimetrically using a commercial diagnostic kits according to manufacturer's instruction at 550, 510, and 550 nm, respectively, using a spectrophotometer (Du 600, Beckman Coulter, Inc., Fullerton, CA, USA), respectively. The concentration of LDL- cholesterol was calculated by Friedwald's formula (Friedwald *et al.,* 1972). The LDL-C : HDL-C ratio was calculated to compare the degree of cardiovascular risk among groups according to (Bermingham *et al.,* 1995).

Determination of total lipids in serum

The method of Frings and Dunn (1970) was used for the determination of total lipids in serum using a standard total lipid (1g/dl). The absorbance of samples and standard against the blank was measured at 530 nm.

Total lipids in serum (g/dL) = A sample x 1/ A standard

fatty acids analysis of blood serum

After being deprived of food for 12 h, the rats were weighed and lightly anaesthetized with diethyl ether. Blood samples were collected from the nick vain and the serum was separated by centrifugation at 3.000 rpm for 20 minutes and was stored at -20°C until used for analysis. Quantitative extraction of total lipids from different serum was carried out following the method of Folch *et al.,* (1957) using chloroform-methanol (2:1 v/v). Fatty acid methyl esters (FAME) (%) were determined by GC as previously described.

RESULTS AND DISCUSSION

Fatty acids composition of vegetable oils

Fatty acidS composition of vegetable oils used in the experimental diets is shown in Table (2). Comparing the fatty acidS composition of vegetable oils used, data showed that CO contained the highest level of 18:2 *n*-6 (56.67 %); FO contained the highest level of 18:3 *n*-3 (60.90%); OO contained the highest level of 18:1 *n*-9 (74.12%); and PO contained the highest level of 16:0 (45.10%). The PO showed the lowest polyunsaturated fatty acids: saturated fatty acids (P:S ratio) (0.18) whereas FO showed the highest (9.60). The CO had the highest *n*-6/*n*-3 ratio (106.92) whereas, the FO showed the lowest (0.23). On the other hand, FO had the highest peroxidisability index (PI) (136.52) while the PO showed the lowest (10.46). Olive oil and flaxseed oil shared a number of characteristics. First, they were uniformly low in saturated fat, secondly, they were either very low in linoleic acid (olive oil) or had a low ratio of linoleic to α-linolenic acid (flaxseed oil), giving them a flavourable ratio of *n*-6 to *n*-3 fatty acids (Simopoulos, 1999).

Table (2): Fatty acids composition of vegetable oils used in the experimental diets (% of total fatty acid methyl esters).

Fatty acid	CO	FO	OO	PO	FO/OO	FO/CO	CO/OO	FO/CO/OO
$C_{14:0}$	0.54			2.01				
$C_{16:1}$	0.09		0.11	0.18	0.42			0.21
$C_{16:0}$	13.25	4.82	13.18	45.10	12.83	7.67	13.15	6.32
$C_{18:1}$	26.75	16.97	74.12	39.10	39.64	22.63	45.85	31.95
$C_{18:2}$ (*n*-6)	56.67	14.30	7.64	9.12	12.62	36.07	37.22	29.75
$C_{18:3}$ (*n*-6)	0.53	60.90	0.61	0.18	31.44	29.86	0.11	30.21
$C_{18:0}$	2.17	3.01	4.34	4.31	3.05	3.77	3.67	1.56
∑SFA's	15.96	7.83	17.52	51.42	15.88	11.44	16.82	7.88
∑ MUFA's	26.84	16.97	74.23	39.28	40.06	22.63	45.85	32.16
∑ PUFA's	57.20	75.20	8.25	9.30	44.06	65.93	37.33	59.96
P : S ratio	3.58	9.60	0.47	0.18	2.77	5.76	2.22	7.61
n-6/*n*-3	106.92	0.23	12.52	50.67	0.40	1.21	338.36	0.98
Peroxidisability Index*	58.40	136.52	10.72	10.46	76.50	96.36	38.59	90.17

CO: Corn oil; FO: Flaxseed oil; OO: Olive oil; PO: Palm oil; F/O: Flaxseed oil/olive oil; FO/CO: flaxseed oil/corn oil; CO/OO: corn oil/olive oil and FO/CO/OO: Flaxseed oil/corn oil/olive oil.

- **Peroxidisability Index (Du *et al.*, 2003) as calculated as follows: (% monenes x 0.025) + (% dienes x 1) + (% trienes x 2) + (%tetraenes x 4) + % hexaenes x 8.**
- **P:S ratio : Total polyunsaturated fatty acids : Total saturated fatty acids**
- **SFA's : Saturrated fatty acids**
- **MUFA's: Monounsaturated fatty acids**

PUFA's: Polyusaturated fatty acids

Comparing the dietary oil mixtures, data revealed that the FO/OO contained the highest contents of 18:3 (n-3) (31.44%), the FO/CO contained the highest contents of 18:2 (n-6) (36.07%); the CO/OO contained the highest contents of 18:1 (n-9) (45.85%) and 18:2 (37.22%); whereas, the FO/CO/OO contained approximately the same contents of 18:1 (31.95%); 18:2 (29.75%); and 18:3 (30.21%). The dietary FO/CO/OO showed the highest P : S ratio (7.61), whereas, the dietary CO/OO showed the lowest ratio (2.22). The

dietary CO/OO, on the other hand, showed the highest *n*-6/*n*-3 (338.36), whereas the dietary FO/OO showed the lowest (0.40), the dietary FO/CO had the highest PI (96.36), whereas the dietary CO/OO showed the lowest (38.59) as compared to the other dietary oil mixtures. Because the (PI) value represents the degree of unstauration of dietary lipids (Hu *et al.*, 1989 and Saito and Kubo, 2003), it has been used as an indicator of PUFA peroxidation (Naggova *et al.*, 2001). When PI value is at the ideal level, lipid metabolism or antioxidant enzyme activities may be influenced by the dietary P:S ratio (Kang *et al.*, 2003 and 2004). Alternatively, it is possible that the effects of the P: S ratio may be modified by the PI value. However, there are few studies investigated the interrelated effects of dietary PI values and P : S ratio of dietary fatty acids on lipid metabolism (Kang *et al.*, 2005 and Riedger *et al.*,2009).

Growth performance

Effects of different dietary vegetable oils on the growth performance of male rats are shown in Table (3). Results revealed that the body weight gain percentage (BWG %) of rats increased by 212.50; 200.00; 185.71; and 233.33% when fed indivedual FO, CO, OO and PO dietary oils, respectively. These results indicated that feeding rats the dietary PO (source of saturated fatty acids) showed the highest BWG %, whereas, those fed the dietary OO (MUFA *n*-9) showed the lowest the BWG% 185.71%. Nevertheless, rats fed on an either the dietary CO (*n*-6) or the dietary FO (*n*-3) showed 200.0 and 212.5% BWG, respectively.

Table (3): Effect of different vegetable oils and their mixtures on the growth performance of rats

Oil	Initial body wt. (g)	Final body wt. (g)	Wt. gain (g)	Body wt. gain (%)	Feed intake (g)	Feed conversion ratio	Feed efficiency (%)
(PO) (control)	30	100	70	233.33	1512.59	21.61	4.63
(FO)	40	125	85	212.50	837.65	9.85	10.15
(CO)	30	90	60	200.00	675.67	11.26	8.88
(OO)	35	100	65	185.71	984.94	15.15	6.60
(FO/OO)	35	117	77	220.00	672.98	8.74	11.44
(FO/CO)	30	85	55	183.33	969.28	17.62	5.67
(CO/OO)	45	150	105	233.33	784.17	7.47	13.39
(FO/CO/OO)	43	100	57	132.56	1116.18	19.58	5.11

CO: Corn oil; FO: Flaxseed oil; OO: Olive oil; PO: Palm oil; F/O: Flaxseed oil/olive oil; FO/CO: flaxseed oil/corn oil; CO/OO: corn oil/olive oil and FO/CO/OO: Flaxseed oil/corn oil/olive oil.
% weight gain = (final weight – initial weight) x 100/initial weight.
Feed conversion = feed consumption/body weight gain
Feed efficiency = weight gain x 100/feed intake.

Rats fed the dietary mixture of FO/CO oils (1:1 v/v) showed the lowest BWG% (183.33%) as compared to those fed the dietary FO/OO (1:1 v/v) (220.00%) or to those fed the dietary CO/OO (1:1 v/v) (233.33%). The BWG% of rats fed the dietary mixture of FO/CO/OO (1:1:1 v/v), on the other hand, showed the lowest body weight gain (132.56%) as compared to the all other dietary vegetable oils studied. These results revealed that incorporation of a CO or a FO with OO at a ratio (1:1 v/v) increased the BWG % of rats

(i.e., 220.00 % in case of FO/OO and 233.33 % in case of CO/OO as compared to 185.71% for the single dietary OO. Data also revealed that incorporation of CO with FO or vice versa in the FO/CO mixture decreased the BWG% to 183.33 % as compared to the single dietary vegetable oil by itself. These result indicated that feeding rats on dietary oils highly in either (*n*-3) or (*n*-6) fatty acids by itself increased the BWG % of rats to 212.50 and 200.00%, respectively. However, addition of *n*-6 (CO) was more effective when combined with *n*-9 (OO) as in the CO/OO (233.33 %) than the effect of addition of *n*-3 (FO) to *n*-9 (OO) as in FO/OO (220.00 %). On the other hand, feeding rats the dietary mixture containing *n*-3 and *n*-6 such as FO/CO (1:1 v/v) decreased the BWG% to 183.33%.

Data also revealed that rats consumed the largest amounts of feed intake in the case of the dietary PO (1512.59 g) during the three months feeding, followed by the dietary OO *n*-9 (984.94 g); FO *n*-3 (837.65 g) and finally CO *n*-6 (675.67 g). Nevertheless, rats consumed less amounts of feed intakes such as 672.98; 969.28; 784.17; and finally 1116.18 g when fed on FO/OO; FO/CO; CO/OO; and FO/CO/OO, respectively.

The single dietary FO showed the best feed conversion ratio (FCR) (9.85%), followed by the dietary CO (11.26 %); OO (15.15 %) and finally, PO which showed the lowest FCR (21.61 %). The lower the FCR value, the better the feed conversion in animals. These values of FCR explained the highest increase in BWG% in rats fed on FO as compared to rats that fed on CO or OO. Again, data revealed that the FCR improved when OO (*n*-9) was added to CO (*n*-6) as in the CO/OO dietary mixture (7.47) and when FO *(n*-3) was added to the OO(*n*-9) as in the FO/OO dietary mixture (8.74) as compared to their corresponding single FCR values. Mixing CO(*n*-6) with FO (*n*-3) as in the FO/CO dietary mixture, however, decreased the FCR (17.62) as compared to their corresponding single values. Rats fed the dietary mixture of FO/CO/OO, however, showed 19.52 FCR. These results supported the previous finding that the increase in BWG was related to the FCR occurred in the animals. The lower the FCR value the higher BWG obtained in the animals i.e rats fed on CO/OO showed the lowest FCR value (7.47) and showed the highest BWG (233.33%), whereas, rats fed on FO/OO showed 8.74 FCR and showed 220.00% BWG . Those rats fed on FO/CO showed 17.62 FCR and showed 183.33% BWGwhile rats fed on FO/CO/OO showed 19.58 FCR and 132.56 % BWG.

Once again, data revealed that the feed efficiency % (FE%) was the highest with rats fed on FO (10.15%), followed by those rats that fed on CO (8.88%); OO (6.60%); and finally PO (4.63%). The FE% was improved in animals that fed on CO/OO (13.39%); followed by those fed on FO/OO (11.44%). On the other hand, the FE % decreased to the lowest value when animals fed on FO/CO (5.67%) as compared to the other oil mixtures. The FE% of animals fed on FO/CO/OO was the lowest (5.11%) as compared to all other dietary mixtures. These results of FE% confirmed the results of BWG obtained. The higher the FE%, the lower the FCR and the higher the BWG % obtained in animals.

From the above results, it could be concluded that feeding animals on the dietary *n*-3 improved the BWG, FCR, and FE%; followed by the dietary

(*n*-6); (*n*-9); and finally by the dietary highly saturated oil such as PO, respectively. The dietary CO *n*-6 and FO (*n*-3) improved the BWG, FCR and FE% when the OO *n*-9 was added to them, respectively. However, the improvement was more effective with FO than with CO. Neverthless, feeding animals on the dietary mixture of FO/CO/OO (1:1:1 v/v/v), on the other hand, decreased the BWG, FCR and FE %.

Alternations in dietary fat composition can influence metabolic functions and lead to changes in body weight and/or composition. The PUFA (*n*-3) have received considerable interest because their consumption has been associated with beneficial health effects. Available data on the effects of different types of PUFA on body adiposity are controversial. It has been reported that a (*n*-3) PUFA such as fish oil could elevat body fat and lower body protein content, whereas a *n*-6 rich diet could not induce obesity in rats (Dulloo, *et al.*, 1995). These finding was confirmed with the present results. Gaiva *et al.* (2001) found that enrichment of the diet with *n*-3 PUFA decreased adipose tissue lipolysis, whereas *n*-6 PUFA increased the uptake of diet-derived lipids by this tissue, both effects favoring fat deposition. Conversely, the consumption of 60% of dietary energy as *n*-3 fatty acids prevented obesity in mice, whereas the *n*-6 rich diet did not produce these effects (Tsuboyama-Kasaoka *et al.*, 1999). Animals fed diets containing OO or high oleic acid- sunflower oil (HOSO) had similar body weights, but these were higher than those fed the fish oil (Ruiz-Gutierrez *et al.,* 1999).

Effects of dietary oils on serum lipids composition

Effects of feeding rats on different vegetable oils having different omega fatty acids on the composition of serum lipids were investigated and are shown in Table (4). Data revealed that the total lipids (TL) in serums of rats decreased as the degree of unsaturation increased. Serum lipids of rats fed on PO (the most saturated oil) showed the highest TL (1003.20 mg/dl), followed by those fed on OO *n*-9 (900.00 mg/dl); on CO *n*-6 (850.10 mg/dl) and finally those fed on FO *n*-3 (829.00 mg/dl). Nevertheless, mixing different vegetable oils increased the TL in serum lipids as compared to the corresponding values of individual oil.

Table (4): Effects of different dietary oils on composition of serum lipids of rats.

Dietary Oil	TL	TG		TC	HDL-C		LDL-C		VLDL-C		LDL/HDL
	mg/ml	mg/ml	%	mg/dl	mg/ml	%	mg/ml	%	mg/ml	%	
PO (Control)	1003.20	840.63	83.79	224.00	30.00	13.39	169.00	75.45	25.00	11.16	5.63
FO	829.00	515.21	62.21	120.84	63.53	52.57	50.19	41.53	6.81	5.64	0.79
CO	850.10	577.77	67.96	125.43	52.06	41.50	61.83	49.29	11.54	9.20	1.19
OO	900.00	681.25	75.69	128.20	60.42	47.13	58.40	45.55	9.38	7.32	0.97
FO/OO	980.60	690.50	70.42	107.90	55.84	51.75	44.16	41.18	7.25	6.72	0.79
FO/CO	885.45	616.71	69.65	105.24	53.86	51.18	42.23	40.13	9.15	8.69	0.78
CO/OO	916.12	663.13	72.15	115.20	48.91	42.46	55.84	48.49	10.42	9.07	1.14
FO/CO/OO	782.92	492.34	62.89	104.09	59.12	56.80	37.56	36.08	7.82	7.51	0.64

FO= Flaxseed (*n*-3); CO= Corn (*n*-6); OO= Olive oil (*n*-9); FO/OO= Flaxseed /Olive; FO/CO= Flaxseed /Corn; CO/OO= Corn oil/Olive; FO/CO/OO= Flaxseed/ Corn/Olive.TL=Total lipids; TG= Triacylglycerol; TC= Total cholesterol; HDL-C= High-density lipoprotei*n*- cholesterol;

LDL-C=Low- density lipoprotei*n*- cholesterol; VLDL-C= Very-low density lipoprotei*n*-cholesterol.

Feeding rats on FO/OO (1:1 v/v) showed higher TL content (980.6 mg/dl) than those fed the single dietary FO (829.00 mg/dl), or to those fed the single dietary OO (900.00 mg/dl). The same trends were also found when the rats fed on FO/CO or when fed on CO/OO. The highest TL, however, was obtained when rats fed on FO/OO (*n*-3/*n*-9) (980.60 mg/dl) as compared to that obtained in case of feeding on CO/OO (*n*-6/*n*-9) (916.12 mg/dl) or in the case of feeding on FO/CO oils (*n*-6/*n*-3) (885.45 mg/dl). On the other hand, the TL decreased to the lowest content when rats fed the dietary mixture of FO/CO/OO (1:1:1 v/v) (782.92 mg/dl).

Once again, the triacyglycerols (TG) in rats serum lipids decreased with increasing the degree of unsaturation in the dietary vegetable oils. Rats fed on PO showed the highest TG content (840.63 mg/dl) and the highest increase in the TG % (83.79%) relative to its TL content; followed by that fed on OO (75.69%); CO (67.96%); and finally that fed on FO (62.21%) meaning that the polar lipids in the serum lipids increased with increasing the degree of unsaturation. Furthermore, the TG increased when rats fed the dietary mixture of vegetable oils as compared to their corresponding of individual dietary oil. The highest increase in the TG was obtained when rats fed on CO/OO (1:1) (72.15%), whereas rats fed on FO/CO showed the lowest increase in the TG% (69.65%). On the other hand, rats fed on a mixture of FO/CO/OO showed 62.89% TG relative to its TL.

Data revealed that, once again, the total cholesterol (TC) contents decreased as the dietary oils increased in the degree of unsaturation. Rats fed on PO (high in saturation) showed the highest TC content (224.00 mg/dl); Data, however, showed no clear differences in TC among rats fed on FO; CO; or OO. Nevertheless, the values were lower than that found with dietary PO. A total cholesterol content below 200 is considered normal. If rises to 250, it increase twice the normal risk of CHD. If it climbs to 300, the risk doubles again. If it is 350 and beyond, it has eight times the normal risk of having diseased and constricted arteries (Miller and Vogel,1996). The TC content, on the other hand, was reduced when rats fed dietary mixtures of vegetable oils. Feeding rats a dietary FO/CO showed the lowest TC content (105.24 mg/dl); followed by dietary FO/OO (107.90 mg/dl), and CO/OO (115.2 mg/dl). These results indicated that FO (*n*-3) reduced the TC contents in serum lipids when added to the other dietary oils. This effect, however, was augmented when added to the dietary CO (*n*-6) rather than with OO (*n*-9). CO (*n*-6) was less effective, to some extent, with OO (*n*-9) than FO (*n*-3) with OO (*n*-9) when incorporated in the dietary feed. Feeding rats the dietary mixture of FO/CO/OO (1:1:1), however, further decreased the TC content to 104.09 mg/dl.

High- density lipoproteins cholesterol (HDL-C) showed the same trends as for TG and TC. Feeding rats FO (*n*-3) showed the highest HDL-C (63.53 mg/dl), representing 52.57% of the TC content. Dietary PO , on the other hand, showed the lowest HDL-C (30.00 mg/dl), representing 13.39% of the TC content. Feeding the rats the dietary CO (*n*-6) and those fed the

dietary OO (*n*-9) showed 52.06 and 60.42 mg/dl, representing 41.50 and 47.13% of the TC, respectively. It is interesting to note that OO had more beneficial effect on HDL-C than CO. Incorporation of OO (*n*-9) with FO (*n*-3) in the FO/OO dietary mixture or with the CO (*n*-6) in the CO/OO dietary mixture decreased the HDL-C to 55.84 and 48.91 mg/dl, representing 51.75 and 42.46% of the TC content, respectively. On the other hand, rats fed the dietary FO/CO showed (53.86 mg/dl) with (51.18 %) of the TC. Furthermore, the HDL-C of rats fed the dietary mixture of FO/CO/OO was 59.12 mg/dl representing 56.80% of the TC.

On contrast to HDL-C, the low-density lipoproteins-cholesterol (LDL-C) and very low-density lipoprotein-cholesterol (VLDL-C), increased with increasing the degree of saturation. Feeding rats the dietary PO showed the highest LDL-C (169.00 mg/dl) and VLDL-C (25.00 mg/dl), representing 75.45 % and 11.16% of the TC content, respectively. Rats fed on FO (*n*-3), however, showed the lowest LDL-C (50.19 mg/dl) and the lowest VLDL-C (6.81 mg/dl) with 41.53% and 5.64% of the TC, respectively. Rats fed on CO (*n*-6) and that fed the dietary OO (*n*-9) showed 61.83 and 58.40 mg/dl LDL-C, representing 49.29 % and 45.55 % of the TC, whereas, the VLDL-C were 11.54 and 9.38 mg/dl, representing 9.20% and 7.32 % of the TC content, respectively. At this point, it is interesting to clear that the present results revealed that OO (*n*-9) showed lower VLDL-C than CO (*n*-6). It is also interesting to note that incorporation of OO (*n*-9) with the FO (*n*-3) in the dietary FO/OO decreased the LDL-C content to 44.16 mg/dl with the same percentage of 41.18 % relative to the TC as compared to 41.53% for the single dietary FO, whereas, when mixed with CO (*n*-6) in CO/OO dietary mixture caused a little decrease in the LDL-C content to 55.84 mg/dl with 48.49 % of the TC as compared to 61.83 mg/dl with 49.29% with the single dietary CO. In either dietary mixture FO/OO or CO/OO, the LDL-C was lower than that observed for the dietary single OO. The LDL-C decreased when rats fed the dietary FO/CO and was 42.23 mg/dl with 40.13% of the TC and further decreased with the dietary mixture of FO/CO/OO to 37.56 mg/dl, representing 36.08% of the TC.

Rats fed the dietary FO/OO (*n*-3/*n*-9) showed the lowest VLDL-C content 7.25 mg/dl with 6.72 % of the TC as compared to that fed the other dietary mixtures. Rats, however, fed the dietary CO/OO; FO/CO; and FO/CO/OO showed 10.42; 9.15; and 7.82 mg/dl with 9.07, 8.69 and 7.51% of the TC contents, respectively.

The high intake of SFA is associated with a high level of serum cholesterol and strongly correlated with death rates. Also, the hyoercholesterolaemic effect is influenced by the level of SFA rather than by the amount of total fat in the diet (Muller *et al.*, 2003 and Chattipakom *et al.*,2009). However, the effects of dietary PUFA on regulation of lipid metabolism and on prevention of CHD appear to be diverse (Lee *et al.,* 1989; Muller *et al.,* 2003; and Satio and Kubo, 2003). In many studies, a balanced intake of dietary PUFA and SFA was thought to be very important in regulating serum cholesterol (Lee *et al.,* 1989; Du *et al.,* 2003; and Muller *et al.,* 2003). The degree to which different SFA exert their cholesterol-raising

effects is still unknown (Temme *et al.,* 1997). They concluded that both lauric and palmitic acids were hypercholesterolemic compared to oleic acid.

Lauric acid raised TC concentrations more than palmitic acid, which is partly due to a strong rise in HDL-C. Early metabolic studies implicated all saturated fatty acids equally in elevated cholesterol responses to animal based fats. However, it is now clear that it is mainly lauric, myristic and palmitic fatty acids (C_{12}-C_{16}) which are responsible for increasing plasma TC. Stearic acid (18:0), has been shown not to increase TC or LDL concentrations (Bonanome and Grundy, 1988). The reason may be that stearic acid rapidly desaturaed into oleic acid, in contrast, palmitic acid (16:0) appeared to be converted relatively slowly to oleic acid, and thus tends to accumulate in the body (Grundy 1988).). Keys *et al.,* (1965) indicated that for every one percent of total dietary energy in which oleic acid is substituted for saturated fatty acids, the serum total cholesterol concentrations falls by an average of 2.7 mg/dl.

The effects of MUFA rich diets, however, compared to those that are rich in PUFA as well as the effects of an intake of single oils compared to oil mixture, however, are controversially discussed and results are contradictory. Wagner *et al.,* (2001) reported that the intervention of two weeks for each diet and the following cross over the corn oil diet had more influence on lipoprotein metabolism than MUFA-rich diet.. Omega-3 fatty acids in high concentrations may reduce blood levels of TG, which may be responsible for their impact on the risk of CHD. However, which fatty acids may be important for altering lipid profiles has not yet to be investigated (Moyad, 2005).

In conformity of the present results, Yang *et al.,* (2005) concluded that ALA from flaxseed oil possessed hypocholesterolaemic activity while conjugated linolenic acid (CLN) had no effect on blood cholesterol, at least in hamsters.. In the present study, the serum LDL-C concentrations were affected by the dietary oils, being the highest with SFA (palm oil); PUFA (*n*-6) CO; MUFA (*n*-9) OO; and was the lowest with PUFA (*n*-3) as FO.

In many studies, serum LDL, HDL, and LDL: HDL ratios has been known as a risk marker for CHD (Ehnholm *et al.,* 1982; Green *et al.,* 1985; Muller *et al.,* 2003). The serum LDL concentration is positively associated with the incidence of CHD.. LDL:HDL ratio has been known as an important factor to predict the evidence of CHD (Green *et al.,* 1985). When this ratio is higher than 5, it means a serious risk sign in CHD (Meyer *et al.,* 2004). In the present study, apart from the dietary PO which showed the highest LDL/HDL ratio (5.63), all the other dietary oils showed normal LDL: HDL ratios and were lower than 2. These results suggest that the dietary PO might has a serious risk sign in CHD, while the other dietary oils have no risk sign of CHD. The value of LDL/HDL ratio was the lowest with the dietary FO (0.79), followed by the dietary OO (0.97), and the dietary CO (1.19). These results indicate that the LDL/ HDL ratio was independent of the degree of unsaturation and the *n*-3 fatty acids was the most effective > *n*-9 fatty acids > *n*-6 fatty acids in reducing the risk sign of CHD.

Results of the present study also revealed that incorporation of FO with another oil reduced the LDL/HDL ratio. The dietary mixture of FO/OO and FO/CO reduced the ratio to 0.79 and 0.78 respectively. The dietary

CO/OO, however, showed 1.14 LDL/HDL. The LDL/HDL ratio was further reduced to the lowest value with the dietary mixture of FO/CO/OO to 0.64.

Table (5) shows the effects of feeding different dietary vegetable oils on the fatty acid composition (%) of serum lipids of rats. Data, generally, revealed that the fatty acid profiles was markedly affected by the dietary oil used. The serum of rats fed on the dietary FO showed the highest total short chain fatty acids (SCFAs) 10.247% followed by those fed on the dietary OO (9.429%). The serum of rats fed on the dietary CO and PO, on the other hand, showed the lowest SCFA content (3.104 and 2.931%, respectively). Nevertheless, serum of rats fed on the dietary mixture FO/CO/OO showed the highest SCFA (12.664%)followed by those fed on the dietary mixture FO/OO (8.576%); FO/CO (7.815%) and finally those fed on the dietary mixture CO/OO (3.003%).

The total long chain saturated fatty acids (LCSFAs) content was approximatelly the same in all serums of rats fed on different dietary oil and ranged from 15.917 to 18.662%. Palmitic acid, nevertheless, was the dominant acid among this group and its content ranged from 13.564 to 16.328%.

The monoenes (n-9) content was the highest in the serum of rats fed on the dietary OO (50.066%), followed by 46.609 % in the serum of rats fed on PO. On the other hand, the serum of rats fed on FO showed the lowest content (20.246%) as compared to the other single oil diets. The serum of rats fed on the dietary mixture of CO/OO, however, showed the highest content (49.305%), followed by 44.061% in the serum of rats fed on FO/OO and 27.492% in the serum of rats fed on FO/CO.

Table (5): Effects of different dietary vegetable oils on the fatty acids composition (%) of rat serum.

Fatty acids	CO	FO	OO	PO	FO/OO	FO/CO	CO/OO	FO/CO/OO
1. Short chain saturated fatty acids (SCSFA)								
$C_{2:0}$	1.142	0.565	1.491	0.288	0.522	0.801	0.000	0.602
$C_{4:0}$	0.000	1.066	0.619	0.250	0.679	0.595	0.230	1.815
$C_{6:0}$	0.000	0.087	0.000	0.000	0.134	0.000	0.551	1.325
$C_{8:0}$	0.261	0.543	0.583	0.384	0.643	0.457	0.000	0.633
$C_{12:0}$	0.155	0.304	0.000	0.000	0.224	0.480	0.106	0.000
∑ SCSFA	**1.559**	**2.565**	**2.693**	**0.922**	**2.202**	**2.333**	**0.891**	**4.375**
Short chain unsaturated fatty acids (SCUFA)								
$C_{2:1}$	0.000	0.064	0.194	0.000	0.000	0.000	0.000	0.188
$C_{4:1}$	0.108	1.939	1.434	0.263	0.846	0.913	0.316	2.536
$C_{6:1}$	0.000	3.065	2.055	0.927	2.503	2.036	0.952	3.087
$C_{7:1}$	0.366	1.576	1.324	0.650	1.664	1.201	0.000	0.361
$C_{8:1}$	0.136	0.165	0.219	0.000	0.203	0.190	0.317	0.426
$C_{9:1}$	0.154	0.184	0.371	0.000	0.232	0.316	0.141	0.000
$C_{12:1}$	0.254	0.203	0.433	0.169	0.289	0.318	0.116	0.426
$C_{12:2}$	0.528	0.194	0.275	0.000	0.233	0.000	0.121	0.378
$C_{12:3}$	0.000	0.292	0.491	0.000	0.404	0.508	0.149	0.887
∑ SCUFA	**1.546**	**7.682**	**6.796**	**2.009**	**6.374**	**5.482**	**2.112**	**8.289**
T. SCFA	**3.104**	**10.247**	**9.429**	**2.931**	**8.576**	**7.815**	**3.003**	**12.664**
2. Long chain saturated fatty acids (LCSFA)								
$C_{14:0}$	0.257	0.184	0.446	0.000	0.251	0.341	0.103	0.396

$C_{15:0}$	0.136	0.157	0.000	0.123	0.112	0.172	0.176	0.188
$C_{16:0}$	14.486	13.564	15.260	16.328	15.590	14.181	14.170	14.271
$C_{17:0}$	0.274	0.275	0.000	0.170	0.166	0.246	0.222	0.275
$C_{18:0}$	0.678	0.616	0.576	0.859	0.302	0.444	0.444	0.382
$C_{19:0}$	0.000	1.270	0.000	0.000	0.000	0.000	0.049	2.199
$C_{20:0}$	1.644	1.894	0.000	0.706	0.000	1.457	0.210	0.000
$C_{22:0}$	0.000	0.000	0.000	0.476	0.000	0.000	0.543	0.000
∑ LCUFA	**17.329**	**17.960**	**16.282**	**18.662**	**16.421**	**16.841**	**15.917**	**17.711**

Continued

Fatty acids	CO	FO	OO	PO	F/O	F/C	C/O	F/C/O
3.Monoenes								
$C_{14:1}$ (*n*-9)	0.307	0.214	0.368	0.217	0.352	0.240	0.063	0.000
$C_{15:1}$ (*n*-9)	0.296	0.092	0.000	0.179	0.000	0.000	0.153	0.000
$C_{16:1}$ (*n*-9)	0.250	0.133	1.472	0.238	0.000	1.905	0.289	0.000
$C_{17:1}$ (*n*-9)	0.491	0.166	0.382	0.439	0.318	0.480	0.301	0.909
$C_{18:1}$ (*n*-9)	21.430	13.159	38.648	35.000	35.816	15.831	36.810	7.633
$C_{20:1}$ (*n*-9)	10.005	6.482	6.167	8.527	4.830	4.199	7.645	7.507
$C_{22:1}$ (*n*-9)	0.404	0.000	3.029	2.009	2.747	4.857	0.044	2.284
∑ MUFA	**33.183**	**20.246**	**50.066**	**46.609**	**44.061**	**27.492**	**49.305**	**18.333**
4.PUFA (ω-6)								
$C_{14:2}$ (*n*-6)	0.417	0.588	0.585	0.618	0.663	0.542	2.751	1.731
$C_{16:2}$ (*n*-6)	0.610	0.909	0.000	1.886	1.054	0.447	1.060	0.768
$C_{17:2}$ (*n*-6)	0.683	0.544	0.000	0.739	0.653	0.000	0.487	0.733
$C_{18.2}$ (*n*-6)	24.979	22.899	8.796	10.074	8.585	16.353	8.010	17.020
$C_{20:2}$ (*n*-6)	0.000	0.582	0.242	0.424	0.495	0.094	0.397	0.000
$C_{20:3}$ (*n*-6)	0.000	0.395	0.000	0.571	0.395	0.000	0.360	0.000
$C_{20:4}$ (*n*-6)	10.599	0.412	0.000	0.276	0.380	0.679	0.178	0.122
$C_{22:2}$ (*n*-6)	0.000	0.990	3.026	4.973	3.770	2.662	3.563	0.886
$C_{22:3}$ (*n*-6)	0.000	0.018	0.609	0.631	0.796	1.184	0.712	1.240
$C_{22:2}$ (*n*-6)	0.000	0.972	0.000	0.388	1.435	0.423	0.213	0.176
$C_{22:5}$ (*n*-6)	7.731	0.000	10.907	10.919	0.369	0.000	9.195	0.000
∑ PUFA	**45.018**	**29.309**	**24.165**	**31.499**	**18.595**	**22.384**	**26.926**	**23.676**
5.PUFA (ω-3)								
$C_{18:3}$ (*n*-3)	1.220	11.516	0.000	0.301	0.290	9.604	0.690	10.223
$C_{20:5}$ (*n*-3)	0.000	0.604	0.000	0.000	1.266	1.308	0.506	5.696
$C_{22:6}$ (*n*-3)	0.000	9.819	0.000	0.000	10.735	14.702	3.653	11.608
∑ PUFA	**1.220**	**21.939**	**0.000**	**0.301**	**12.291**	**25.614**	**4.849**	**27.527**
Total usatd.	80.97	79.18	81.03	80.42	81.32	80.97	83.19	77.80
Total satd.	19.03	20.82	18.97	19.58	18.68	19.03	16.81	22.20
Tunst/T sat	4.25	3.80	4.29	4.11	4.35	4.25	4.95	3.50
***n*-9/*n*-6**	0.95	0.69	2.07	1.48	2.37	1.23	1.83	0.77
***n*-6/*n*-3**	36.90	1.34	------	104.65	1.51	0.87	5.55	0.86

CO (Corn oil); FO (Flaxseed oil); OO (Olive oil); PO (Palm oil); FO/OO (Flaxseed oil/ Olive oil (1:1 v/v); FO/CO (Flaxseed oil/ Corn oil 1:1); CO/OO (Corn oil/Olive oil 1:1); and FO/CO/OO (Flaxseed oil/Corn oil/Olive oil 1:1:1).

However, serum rats fed on the dietary mixture FO/CO/OO showed the lowest content (18.333%) as compared to other dietary mixtures. Oleic acid was the most dominant and ranged from 13.159 to 38.648% in the single oil diets and from 7.633 to 36.810% in the dietary oil mixtures. C 20:1 n-9 was the second dominant acid in this group and ranged from 6.167 to 10.005 in the single oil diet and from 4.199 to 7.507% in the dietary oil mixtures.

The total PUFAs (n-6) content was the highest in the serum of rats fed on the dietary CO (45.018%), followed by 31.499 % in the serum of rats fed on PO. On the other hand, the serum of rats fed on OO showed the lowest content (24.165%) as compared to the other single oil diets. The serum of rats fed on the dietary mixture of CO/OO, however, showed the highest content (26.926%), followed by 23.676% in the serum of rats fed on FO/CO/OO and 22.384% in the serum of rats fed on FO/CO. However, serum rats fed on the dietary mixture FO/OO showed the lowest content (18.595%) as compared to other dietary mixtures.

The total PUFAs (n-3) content was the highest in the serum of rats fed on the dietary FO (21.939%), followed by 1.220 % in the serum of rats fed on CO. On the other hand, the serum of rats fed on OO or PO showed the no or traces. The serum of rats fed on the dietary mixture of FO/CO/OO, however, showed the highest content (27.527%), followed by 25.614% in the serum of rats fed on FO/CO and 12.291% in the serum of rats fed on FO/OO. However, serum rats fed on the dietary mixture FO/CO showed the lowest content (4.849%) as compared to other dietary mixtures.

It seems intresting to note that the total unsaturated as well as the total saturated fatty acids and hence, the ratio between them. They showed approximatelly the same content within the group in all serums fed on different dietary either single or in a mixture. Roes *et al.* (2004) reported that it should be realized that the fatty acids profile of adipose tissues are reflection of the intake and metabolism of fatty acids in the last days prior to slaughter, wheras the fatty acid composition of organ tissues are global refelection of the livelong fatty acid metabolism of the animals. Nevertheless, it is believed that a comparison of the fatty acid profiles of different organs may reveal some insight into fatty acid metabolism. Therefore the present study revealed that it was not the total unsaturation or the total saturation the effect on the profile of serum lipids but the type of an indivedual fatty acid and its omega type. In that respect the ratios of n-9/ n-6 and the ratios of n-6/ n-3 were the cornerstone i.e. the ratio n-6/n-3 in serum rats fed on the dietary PO showed the highest (104.65), followed by those fed on CO (36.90), however the serum of rats fed on FO showed the lowest ratio (1.34).

In conclusion, the present results confirmed the previous reported results that high intake of SFA is associated with a high level of serum cholesterol and strongly correlated with coronary death rates. However, the effects of the dietary PUFA on prevention of CHD appear to be diverse and frequent consumption of PUFA (*n*-3), MUFA (*n*-9), PUFA (*n*-6) are associated with reducing the coronary mortality in the same order. Intake of *n*-3 fatty acids improves platelet function, blood viscosity, blood flow and blood pressure, as well as, HDL and TG concentrations, and all of which are thought to be related to risk for coronary heart disease events (Morris *et al.,* 1993).

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دراسة مقارنة لتأثير الأحماض الدهنية (الأوميجا) المختلفة على كفاءة النمو ومكونات ليبيدات السيرم فى الفئران

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تم دراسة التأثير المقارن للأحماض الدهنية الاوميجا على كفاءة النمو ومكونات ليبيدات السيرم فى الفئران باستخدام (١٢٠ فأر) تم تغذيتهم على وجبة اساسية لمدة اسبوعين قبل التغذية على الوجبات التجريبية. قسمت فئران التجربة على ثمان مجموعات كل منها ١٥ فأر , تم تغذية كل مجموعة على زيت او خليط زيوت كمصدر وحيد للدهن خلال فترة التجربة وهى ثلاثة شهور حيث تم تقدير كل من كفاءة النمو وليبوبروتينات السيرم وكذلك تركيب الاحماض الدهنية فى السيرم.

أوضحت النتائج تحسن كفاءة النمو فى الحيوانات التى تم تغذيتها على علائق تحتوى على زيت الكتان (اوميجا -٣) يليها تلك المحتوية على زيت الذرة(اوميجا -٦) ثم المحتوية على زيت الزيتون (اوميجا -٩) , ثم الزيوت الاكثر تشبعا (زيت النخيل) . كماسجلت المجموعة التى تم تغذيتها على زيت النخيل أعلى محتوى من الليبيدات الكلية فى السيرم وأقلها لتلك التى تم تغذيتها على زيت الكتان . كما أظهرت المجموعة التى غذيت على زيت النخيل أعلى محتوى من الكولسترول الكلى بينما لم يكن هناك اختلافات واضحة بين المجاميع التى تم تغذيتها على زيت الذرة أو زيت الكتان أو زيت الزيتون وان كانت جميعها أقل من زيت النخيل.

أوضحت الدراسة أن التغذية على خليط من زيت الكتان والذرة والزيتون بنسبة ١:١:١ أدت الى خفض محتوى الكولسترول الكلى كما لوحظ أن خليط زيت الذرة مع زيت الزيتون أقل كفاءة فى ذلك مقارنة بزيت الكتان مع زيت االزيتون.

اوضحت النتائج ان التغذية على زيت الكتان زادت من نسبة الليبوبروتينات مرتفعة الكثافة (الكولسترول عالى الكثافة) ٥٢,٥٧% فى حين أن نسبته عند التغذية على زيت النخيل كانت ١٣,٣٩ % من الكولسترول الكلى.

كما أظهرت نتائج الدراسة أن تركيب ليبيدات السيرم تأثر بدرجة كبيرة بنوع الزيت المستخدم فى الوجبة.

قام بتحكيم البحث

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