Global Veterinaria 12 (4): 461-469, 2014
ISSN 1992-6197

DOI: 10.5829/idosi.gv.2014.12.04.835

Lipid Profile and Lipogensis Following Corn Oil, Truffle Oil or Wheat Germ Oil Administration in Albino Rat

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Abstract: Eighty adult albino rats were used in Present study to access the correlation between the administration of corn oil, truffle oil or wheat germ oil beside fatty acid synthesis enzymes and serum lipid profile. Significant increase in the level of total lipids, triacylglycerol (TAG), cholesterol, low density lipoprotein (LDL-c) with decrease in the level of high density lipoprotein (HDL-c) in the groups treated with corn oil. Where, truffle oil and wheat germ oil showed significant increase in the level of HDL-c. Significant decrease in the level of Acetyl-coA-carboxylase (ACC), Citrate cleavage enzyme (CCE), Malic dehydrogenase (ME) and Isocitrate dehydrogenase (ICDH) with a significant increase in the enzymatic activity of 6-phosphogluconate dehydrogenase (6-PGDH) in hepatic tissues was also detected. On the other hand, in peripheral adipose tissue, there were an increase in the enzymatic activities of all lipogenic enzymes in the groups treated with corn oil with nearly no change in the groups treated with truffle and wheat germ oil beside, a significant increase in the level of 6-PGDH only in the group treated with germ oil. The result of the present study indicate that the use of these oils could be a valuable source for the protection against coronary heart diseases and associated cardiovascular diseases (CVD) in animals and human.

Key words: Lipid Profile · Enzyme Assay · Corn Oil · Truffle Oil · Wheat Germ Oil

INTRODUCTION

Hyperlipidemia is a major problem in animals and human. Animals feed with high grain diets increases lipid deposition with a predisposing high risk of Hyperlipidemia and cardiovascular diseases. Lipogenesis is controlled by insulin, ACC enzyme and enzymes for citrate shuttle. Those enzymes are responsible for exiting of Acetyl CoA form mitochondria to the cytoplasm with other enzymes responsible for the formation of $NADPH+H^+$, which is needed for the reduction steps in the process of fatty acid synthesis [1]. Generally, fatty acids synthesis, the process of triacylglycerol synthesis starts with acetyl-CoA and builds up by the addition of two carbon units in the form of malonyl CoA, this occurs in the cytoplasm of adipose tissue and liver [2].

Corn oil is extracted from the germ of corn (Maize). It is generally used in animal, human food and industry. Mainly it s used in cooking and a key ingredient in some margarine. Corn oil is also used in industry in soap, salve, paint, rustproofing for metal surfaces, inks, textiles, nitroglycerin and insecticides. It is also used as a carrier for drug molecules in pharmaceutical preparations [3, 4]. Corn oil is composed of saturated fatty acids, 80% palmetic acid (lipid number of C16:0), 14% stearic acid (C18:0) and 3% arachidonic acid (C20:0), over 99% of the

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monounsaturated fatty acids are oleic acid (C18:1) while 98% of the polyunsaturated fatty acids are the omega-6 linoleic acid (C18:2 n-6) with the 2% remainder being the omega-3 alpha-linolenic acid (C18:3 n-3) [5].

Omega-3 polyunsaturated fatty acids play major role in brain development, prevention of different pathologies and cardiovascular diseases. Excessive levels of omega-6 fatty acids, relative to omega-3 fatty acids, may increase the probability of a number of diseases and depression [6-8]. Modern diets typically have ratios of omega-6 to omega-3 in excess of 10 to 1, or 30 to 1. Corn oil has an omega-6 to omega-3 ratio of 49:1. The optimal ratio is thought to be 4 to 1 or lower [9, 10]. A high intake of omega-6 fatty acids may increase the likelihood of developing breast cancer [11], prostate cancer [12]. Inverse association between total polyunsaturated fatty acids and breast cancer risk has been detected [13].

Truffle oil is a modern culinary ingredient, used to impart the flavor and aroma of truffles to food. Most truffle oils are usually extracted with an olive oil [14]. Truffle oil is commonly used to make "truffle fries," which feature French fries tossed in truffle oil, Parmesan cheese, pepper and sometimes other ingredients. Some pasta dishes and whipped dishes such as mashed potatoes or deviled eggs incorporate truffle oil [15].

Wheat germ oil is extracted from the germ of the wheat kernel, which makes up only 2.5% by weight of the kernel. Wheat germ oil contain high level of octacosanol which is an exercise and physical performance enhancing agent. It also has been reported to lower plasma cholesterol in humans [16]. Wheat germ oil is also very high in vitamin E (255 mg/100g) and has the highest content of vitamin E of any food that has not undergone prior preparation or vitamin fortification. It has been explored to be included in increasing blood flow and reaction time. Further uses include treatment of certain skin conditions such as scarring and inflammation [17].

It is reported to be the first experimental study on truffle oil. Our study was designed to compare the correlation between the corn oil, truffle oil or wheat germ oil administration and fatty acid synthesis enzymes in hepatic and peripheral adipose tissue with remarks to serum lipid profile in rats.

MATERIALS AND METHODS

Material: Several oil products have been used in our study. C8267®-Corn oil (Sigma-Aldrich Co. Egypt) in concentration of 0.9 g/ml. Roland Black Truffle Oil® (Roland Co. New York) in a concentration of 10% and W1000®- Wheat germ oil (Sigma-Aldrich Co. Egypt) in concentration of 0.93 g/ml. Oils were given to each individual rat by gavages using stomach tube.

Experimental Animals: Seventy male adult albino rats (120-150 g) were obtained from the Laboratory Animal house, Faculty of Veterinary Medicine, Zagazig University, Egypt. The animals were kept in an environmentally controlled room with clean hygienic metal cages and maintained under a uniform laboratory condition. All animals were under hygienic conditions, given balanced ration and drinking water was allowed *ad.libitum* throughout the experimental period. The study complied with the Animal Welfare Act and was approved by the Zagazig University's Institutional Veterinary Committee.

Experimental Design: Eighty adult albino rats were divided into four groups and each one subdivided into 2 subgroups and acclimatized for 14 days before starting the experiment.

Group 1: (n=20), control group, rats were fed on clean healthy food and water along the experimental period and left under normal condition without any treatment.

Group 2: (n=20), corn oil treated group, subdivided into 2 subgroups treated orally with corn oil (0.1 & 0.2 ml/ rat respectively), daily for 4 weeks.

Groups 3: (n=20), truffle oil treated group, subdivided into 2 subgroups treated orally with truffle oil (0.1 & 0.2 ml/ rat respectively), daily for 4 weeks.

Groups 4: (n=20), wheat germ oil treated group, subdivided into 2 subgroups treated orally with wheat germ oil (0.1 & 0.2 ml/ rat respectively), daily for 4 weeks.

All rats were scarified after 4 weeks, the blood samples and liver tissues were collected for further analysis.

Blood Sampling and Lipoprotein Fractionation: Two-three ml blood was collected after 4 weeks of the experiment from the retro-orbital venous plexus of rats under sterile septic condition. Blood was allowed to flow smoothly into the tubes, left to clot for 2 hours at room

temperature then centrifuged at 3000 rpm for 15 min. The clear supernatant serum was collected using sterile Pasteur pipettes. The collected serum was transferred to dry, labeled eppendorf tubes for determination of lipid profile in serum.

Evaluation of Serum Lipid Profile: Serum total lipids was determined [18], triacylglycerol (TAG) [19], phospholipids [20], total cholesterol [21], HDL-c [22] and LDL-c [23]. All parameters were colorimetric measured using commercial kits provided by Biomerieux, Egypt. All biochemical analysis was done using spectrophotometer 5010 v5+, Berlin, Germany for biochemical serum analysis.

Hepatic and Adipose Tissue Enzyme Assay: The livers were immediately excised as well as peripheral adipose tissues around the kidney (PRAT). Both tissues were taken in ice and homogenized in a Mannitol-Tris-HCl buffer (pH 7.4) [24] followed by centrifugation at 5000 r.p.m. for 10 min. at 4 °C and the supernatant was taken for verifying hepatic total lipids [18] and the enzymatic activities of lipogenic enzymes (Acetyl-coA-carboxylase (ACC) [25], Citrate cleavage enzyme (CCE) [26], Malic dehydrogenase (ME) [27], Isocitrate dehydrogenase (ICDH) [28] and 6-phosphogluconate dehydrogenase (6-PGDH) activity.

Statistical Analysis: The obtained data were analyzed and graphically represented using the statistical package for social science (SPSS, 18.0 software, 2011) for obtaining means and standard error. Duncan's test was used for making a multiple comparisons among the groups for testing the inter-grouping homogeneity [29].

RESULTS

Hepatic Total Lipids: Corn oil (0.1&0.2 ml/rat) and truffle oil (0.2 ml /rat) treated groups showed a significant ($P \leq 0.05$) increase in hepatic total lipids, meanwhile truffle oil (0.1 ml/rat) and wheat germ oil (0.1 &0.2 ml /rat) showed a non significant change.

Serum Lipids and Lipoproteins: Lipid profile showed a significant ($P \leq 0.05$) increase in the level of total lipids, TAG, cholesterol, LDL-c with decrease in the level of HDL-c in the groups treated with corn oil, but the reverse founded by treatment with truffle oil and wheat germ oil which have the greatest effect on lipid profile and increase the levels of HDL-c.

Changes in Serum Total Lipids and Triglyceride Levels: Corn oil (0.1&0.2 ml/rat) and truffle oil (0.2 ml /rat) treated groups showed a significant ($P \leq 0.05$) increase in serum total lipids, meanwhile truffle and wheat germ oil (0.1ml /rat) showed a significant ($P = 0.05$) decrease when compared with control group. There was a non significant change in serum total lipids was observed in wheat germ oil (0.2 ml/rat) treated group (Table 1).

Changes in Serum Phospholipids: Corn oil (0.2 ml/rat) treated groups showed a significant ($P \leq 0.05$) decrease in serum phospholipids, meanwhile truffle and wheat germ oil (0.1& 0.2ml /rat) showed a significant ($P \leq 0.05$) increase when compared with control group. There was a non significant change in serum phospholipids was observed in corn oil (0.1 ml/rat) treated group (Table 1).

Changes in Serum Total Cholesterol and Hdl-c: Corn oil (0.2 ml/rat) treated groups showed a significant ($P \leq 0.05$) increase in serum total cholesterol, meanwhile truffle oil (0.1 ml/rat) and wheat germ oil (0.1& 0.2ml /rat) showed a significant ($P \leq 0.05$) decrease when compared with control group. There was a non significant change in serum total cholesterol was observed in corn oil (0.1 ml/rat) and truffle oil (0.2 ml/rat) treated group (Table 1).

Changes in Serum Ldl-c: Corn oil (0.2 ml/rat) treated groups showed a significant ($P = 0.05$) increase in serum LDL-c, meanwhile corn oil (0.1 ml/rat), truffle and wheat germ oil (0.1& 0.2ml /rat) treated groups showed a non significant change in serum LDL-c when compared with control group (Table 1).

Hepatic and Peripheral Adipose Tissue Enzymes: Hepatic and peripheral adipose tissue enzymes (Table 2&3) showed a significant ($P \leq 0.05$) decrease in the level of Acetyl-coA-carboxylase (ACC), Citrate cleavage enzyme (CCE), Malic dehydrogenase (ME) and Isocitrate dehydrogenase (ICDH) enzymatic activities with a significant increase in the enzymatic activity of 6-phosphogluconate dehydrogenase (6-PGDH) in hepatic tissues. On the other hand, the results were controversial in peripheral adipose tissue as there were an increase in the enzymatic activities of all lipogenic enzymes in the groups treated with corn oil with nearly no change in the groups treated with truffle and wheat germ oil with a significant increase in the level of 6-PGDH only in the group treated with germ oil.

Table 1: Means ± SE of hepatic lipids and serum lipids profile (Total lipids, TAG, Phospholipids, Total cholesterol, HDL-c and LDL-c) in rats following 4 weeks administration of corn oil, truffle oil and wheat germ oil.

		Corn oil		Truffle oil		Wheat germ oil		
	Control group	0.1 ml	0.2 ml	0.1 ml	.2 ml	0.1 ml	0.2 ml	LSD
Hepatic total lipids (mg/dl)	73.5 ±5.8^{de}	111.5±8.2^{b}	123.4±9.2^{a}	78.5±6.3^{d}	92.2±7.9^{c}	66.5±5.4^{e}	74.4±9.8^{d}	7.35
Total lipids (mg/dl)	739.4±14.2^{c}	799.2±16.44^{b}	895±15.8^{a}	701.5±17.4^{d}	793.4±15.1^{b}	699.4±16.7^{d}	732.5±19.1^{c}	29.8
TAG (mg/dl)	109.4± 7.8^{d}	136.5±9.8^{b}	147.3±11.2^{a}	81.4± 8.2^{e}	123.1±9.4^{c}	78.6± 11.2^{e}	107± 9.3^{d}	8.22
Phospholipids (mg/dl)	96.4±7.8^{c}	89±9.7^{c}	75.4±8.3^{d}	113.6±11.2^{b}	115.4±9.9^{b}	123.4±12.8^{a}	115.5±11.2^{b}	7.88
Total Cholesterol (mg/dl)	115.4±11.3^{b}	119.4±9.8^{ab}	123.2±8.7^{a}	95.2±13.4^{c}	91.4±11.2^{b}	93.4±12.6^{c}	89.2±9.8^{c}	8.13
HDL-c (mg/dl)	52.6±3.2^{b}	47.3±2.9^{bc}	45.5±3.8^{c}	62.3±4.6^{a}	53.4±5.3^{b}	64.4±4.7^{a}	59.2±5.1^{a}	5.81
LDL-c (mg/dl)	37.4± 2.5^{bc}	42.9± 3.3^{ab}	45.8±4.1^{a}	33.5± 3.9^{c}	35.4± 5.2^{c}	33.1±2.9^{c}	35.2±3.8^{c}	4.87

** Means within the same rows carrying different superscripts are significant at (P ≤0.05).*

Table 2: Acetyl-coA-carboxylase (ACC), Citrate cleavage enzyme (CCE), Malic dehydrogenase (ME), Isocitrate dehydrogenase (ICDH) and 6-phosphogluconate dehydrogenase (6-PGDH) activities in hepatic tissues of rats following 4 weeks administration of corn oil, truffle oil and wheat germ oil.

		Corn oil		Truffle oil		Wheat germ oil		
	Control group	0.1 ml	0.2 ml	0.1 ml	0.2 ml	.1 ml	0.2 ml	LSD
ACC (nmol malonyl CoA/ min/ mg protein)	3.3 ± 0.09^{a}	1.9±0.1^{b}	1.6±0.2^{cd}	1.4±0.2^{cd}	1.1±0.08^{ef}	1.3±0.09^{de}	0.99±0.07^{f}	0.29
CCE (nmol NAD^{+} / min/ mg protein)	32.5± 1.98^{a}	21.8±4^{bc}	20.6±2.9^{c}	16.6±3.1^{de}	14.2±2.9^{e}	16.8±3.9^{d}	11.5±3.9^{f}	2.38
ME (nmol NADPH/ min/ mg protein)	36.3± 3.6^{a}	30.2±4.1^{b}	24.2± 3.9^{cd}	26.5± 5.2^{c}	23.3± 5.6^{d}	21.6± 4.8^{de}	19.2±3.9^{e}	3.16
ICDH (nmol NADPH/ min/ mg protein)	16.8±1.3^{a}	15.4 ±1.6^{ab}	14.6±1.8^{bc}	12.6±1.6^{c}	14.6±2.1^{bc}	12.9±1.1^{c}	13.6±1.8^{c}	2.11
6-PGDH (nmol NADPH/ min/ mg protein)	96.3± 5.8^{e}	88.3± 6.1^{f}	81.5±4.8^{g}	121.5± 7.9^{b}	105.4± 8.2^{c}	136.6±11.2^{a}	115.4±6.9^{d}	5.42

** Means within the same rows carrying different superscripts are significant at (P ≤0.05).*

Table 3: (Acetyl-coA-carboxylase (ACC), Citrate cleavage enzyme (CCE), Malic dehydrogenase (ME), Isocitrate dehydrogenase (ICDH) and 6-phosphogluconate dehydrogenase (6-PGDH) activities in peripheral adipose tissue of rats following 4 weeks administration of corn oil, truffle oil and wheat germ oil.

		Corn oil		Truffle oil		Wheat germ oil		
	Control group	0.1 ml	0.2 ml	0.1 ml	0.2 ml	0.1 ml	0.2 ml	LSD
ACC (nmol malonyl CoA/ min/ mg protein)	6.1 ± 0.17^{c}	8.2±1.1^{ab}	9.4±1.4^{a}	6.3±0.9^{c}	6.6±1.2^{c}	5.8±1.1^{c}	6.8±1.3^{c}	1.3
CCE (nmol NAD^{+} / min/ mg protein)	533± 12.6^{c}	633±16.4^{b}	691±21.2^{a}	541±18.2^{c}	555±19.3^{c}	531±16.4^{c}	542±15.1^{c}	36.8
ME (nmol NADPH/ min/ mg protein)	342± 9.4^{cd}	405±11.2^{b}	455± 13.2^{a}	349± 13.6^{cd}	362± 17.2^{c}	335± 15.2^{d}	346± 16.2^{cd}	24.5
ICDH (nmol NADPH/ min/ mg protein)	63.6±4.2^{bc}	71.5±6.1^{bc}	82.4±5.5^{a}	68.9±4.9^{bc}	73.4±7.2^{b}	51.2±6.1^{d}	66.2±5.1^{bc}	8.7
6-PGDH (nmol NADPH/ min/ mg protein)	64.8± 5.3^{e}	88.4± 6.2^{cd}	94.3±6.3^{bc}	91.5± 7.8^{cd}	105.5± 8.3^{ab}	93.4±7.4^{bc}	111.4±6.9^{a}	12.4

* Means within the same rows carrying different superscripts are significant at (P ≤0.05).

Changes in Acetyl-coa-carboxylase (ACC), Citrate Cleavage Enzyme (CCE) and Malic Dehydrogenase (ME): Corn oil, truffle oil and wheat germ oil treated groups showed a significant (P≤0.05) decrease in hepatic ACC activity comparing with control group (Table 2). Peripheral adipose tissue ACC showed a significant (P≤0.05) increase in corn oil (0.1 & 0.2 ml/rat) treated group, meanwhile truffle and wheat germ oil treated rats showed a non significant (P≤0.05) change when compared with control group (Table 3).

Changes in Isocitrate Dehydrogenase (ICDH): Corn oil (0.2 ml /rat), truffle oil and wheat germ oil treated groups showed a significant (P≤0.05) decrease in hepatic ME activity comparing with control group, meanwhile Corn oil treated group (0.1 ml /rat) showed a non significant change (Table 2). Peripheral adipose tissue ME showed a significant (P≤0.05) increase in corn oil treated group (0.2ml/rat) with a significant (P≤0.05) decrease in wheat germ oil treated group (0.1 ml/rat). Meanwhile, corn oil (0.1 ml/rat), truffle (0.1&0.2 ml /rat) and wheat germ oil (0.2 ml/rat) treated group showed a non significant change comparing with control group (Table 3).

Changes in 6-phosphogluconate Dehydrogenase (6-PGDH): Corn oil treated rats showed a significant (P≤0.05) decrease in hepatic 6-PGDH activity, meanwhile truffle and wheat germ oil treated groups showed a significant (P≤0.05) increase comparing with control (Table 2). Peripheral adipose tissue 6-PGDH showed a

significant (P=0.05) increase in corn, truffle and wheat germ oil treated rats when compared with control group (Table 3).

DISCUSSION

Coronary heart diseases (CHD) and associated cardiovascular diseases (CVD) in animals and human are the most common cause of death all over the world especially in developing countries [30]. Increasing intake of total lipids, trans-fatty acids and saturated and polyunsaturated fatty acids leading to high incidence of CHD [31]. We proposed that corn, truffle and wheat germ oil administration provide a protection against Hyperlipidemia.

The present study showed an increase in the hepatic total lipids with hyperlipidemia in corn oil fed rats. Corn oil is responsible for Hyperlipidemia, increase of total lipids, triglycerides and low-density lipoprotein cholesterol (LDL-c) along with a decrease in high-density lipoprotein cholesterol (HDL-c). Hyperlipidemia is the predictor of coronary artery disease, fatty liver disease and carcinogenesis and is a predominant risk factor for cardiovascular diseases (CVD) [32]. Decrease in hepatic total lipids was reported in truffle and wheat germ oil fed rats. Wheat germ oil improved the values of the hepatic total lipid and returned these values to around that of the normal value, so it protects against the toxic influence of profenofos on rat tissue lipids [33]. The present result demonstrates that both truffle and wheat oils able to provide protection against many Hyperlipidemia related diseases.

Increasing the level of TGA and phospholipids in corn oil fed rats may be due to the increased synthesis and release of LDL and VLDL from the liver into the circulation. Corn oil administration lead to an increase in TGA and phospholipids level which may positively correlated with hepatic lipogenic enzyme activity. In addition, it decreases the activity of mitochondrial carnitine palmitoyl transferase-1 (PTS-1), resulted in impairment in fatty acid oxidation and lipid accumulation in corn oil fed rats [34]. Truffle and wheat germ oil improve lipid metabolism [35]. They consider a valuable source of polyunsaturated fatty acids, including linoleic acid (ù-6) and linolenic acid (ù-3) [36]. The monounsaturated fatty acid can reduce serum TG and phospholipids level [37]. In addition, wheat germ oil has a number of nutritional and health benefits like high content of vitamin E and phytosterol [38]. This may be the reason of decrease the level of both triglyceride and phospholipids. Truffle and wheat germ oil administration lowered TG level may be due to an increase in membrane permeability and fluidity causing decrease triglycerides, phospholipids and cholesterol levels [39].

Liver plays an important role in the synthesis and net excretion of cholesterol either directly as free cholesterol in the bile or after conversion into bile acid [40]. An increase in serum cholesterol level in corn oil fed rats was reported. This may be due to increased uptake of exogenous cholesterol and subsequent deposition and decreased cholesterol catabolism as evidenced by a reduction in bile acid production and turnover of bile acids [41]. Understanding the mechanism of cholesterol decreasing by truffle and wheat germ oil may be due to the apo-E receptors responsible for hepatic uptake of chylomicron remnants which are not subjected to regulation [42]. Chylomicrons originating from truffle and wheat germ oil administration are therefore totally taken up by the liver. Thus it could be hypothesized that accumulation of lipids by the liver in case of administration of these oils results from the massive uptake of lipids by the intestine and that lower or ayed intestinal absorption [43].

Truffle and wheat germ oil are rich in mixtures of lipophilic volatile organic compounds and α-linolenic acid [44&45]. These results in a higher cholesterol secretion into bile and depletion of the intra-hepatic pool of cholesterol, lead to an increase in cholesterol synthesis and turnover [46]. Moreover, truffle and wheat germ oil reduce hepatic lipid accumulation by stimulating â-oxidation and suppressing fatty acid synthesis [47]. These mechanisms may account for the better regulation of hepatic lipid metabolism. Present results, however, do not exclude a possible effect of wheat germ oil on either biosynthesis or catabolism of liver lipids. The fact that the total blood cholesterol was not modified in the rats administered truffle and wheat germ oil. This is in accordance with the marked resistance of the rat to diet induced hypercholesterolemia [48]. The addition of 7% wheat germ to rat diet reduced VLDL cholesterol by 37.9% [43]. The inclusion is that wheat germ oil reduced plasma chylomicron cholesterol concentrations by 27.1% over several hours in 6 normolipidemic subjects [49], so that wheat germ oil may lower circulating cholesterol or at least delay its absorption.

Corn oil fed rats showed an increase in LDL-c level. It deposited in the interior of blood vessels resulting in hardened arteries, narrowing of the blood vessels and coronary heart disease. Truffle and wheat germ oil causing high level of HDL-c, reduce the harmful effects of

LDL-c. HDL-c picks up and transports cholesterol in the blood back to the liver, leads to its elimination from the body. HDL can help to keep LDL cholesterol from building up in the walls of the arteries [50]. LDL and HDL particles are formed during the subsequent TAG depletion catalyzed by hepatic lipase [51]. The LDL-receptor pathway (Apo B & E receptor) is different from the apo E-receptor route, which enables the uptake of chylomicron remnants from the blood stream [52]. Truffle and wheat germ oil showing a decrease in LDL-c beside the chylomicron cholesterol concentration but the mechanisms by which this reduction is achieved remain to be elucidated. Rats supplemented with wheat germ oil for 10 successive days significantly ameliorated serum lipid profile levels and modulated the alteration in activity of LDH [53].

The present study showed a significant decrease in the level of Acetyl-coA-carboxylase (ACC), Citrate cleavage enzyme (CCE), Malic dehydrogenase (ME) and Isocitrate dehydrogenase (ICDH) enzymatic activities with a significant increase in the enzymatic activity of 6-phosphogluconate dehydrogenase (6-PGDH) in hepatic tissues of corn, truffle and wheat germ oil fed rats. On the other hand, the results were controversial in peripheral adipose tissue as there were an increase in the enzymatic activities of all lipogenic enzymes in the groups treated with corn oil with nearly no change in the groups treated with truffle and wheat germ oil with a significant increase in the level of 6-PGDH only in the group treated with germ oil.

Lipogenesis and the activities of ACC, CCE, ME and ICDH enzymes were closely correlated in rat liver and adipose tissue. The activities of these enzymes decreased at the same time as lipogenesis in the liver of the rats. These enzymes appear to play an important role in hepatic lipogenesis. These enzymes may be involved in the formation of phosphoenolpyruvate from dicarboxylic acids and amino acids in rat liver [54]. Since gluconeogenesis is a very active process in rat liver, a high activity of malate dehydrogenase might be expected. Malic enzyme activities strongly observed in weanling rats [55]. The enzymatic changes may have led to the increase in lipogenesis, or, more likely, they may have been secondary to an increased flow of metabolites from glucose to fatty acid [54]. 6-phosphogluconate dehydrogenase (6-PGDH) is the key enzymes of this pathway which is responsible for the generation of NADPH.H. It plays essential roles in the regulation of oxidative stress by regulating NADPH.H level, the main intracellular reductant. Corn, truffle and wheat germ oil treated rats showed an increase in the hepatic 6-PGD activity. The present results are in agreement with [56] which reported that respiratory mitochondrial enzymes and glycolysis systems were activated by the administration of antioxidants oils. 6-PGD is considered the fundamental enzymes of pentose phosphate pathway activity. The primary results of the pathway are: the generation of reducing equivalents, in the form of NADPH (accounting for approximately 60% NADPH production), used in reductive biosynthesis reactions within cells (e.g. fatty acid synthesis) and production of ribose-5-phosphate (R5P), used in the synthesis of nucleotides and nucleic acids [57]. The inhibition of nucleotide biosynthesis, i.e. formation of ribose component and the phosphorylation of ribonucleotides inhibited protein biosynthesis [58].

In conclusion, the correlation of administration of corn oil, truffle oil or wheat germ oil with lipid profile and lipogensis was clarified in the present experiment. Better results obtained from the administration of truffle oil and wheat germ oil. Future studies will also be needed for the development of bigger scale experiment with the administration of different doses of these oils on different animal species.

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