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Antihyperlipidemic effect of iced black tea (*Camellia sinensis*) extract

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Abstract

The aim of the present study was to elucidate the possible biochemical improving effect in lipid metabolic profile and organ function profiles that may result from continuous treatment with iced *Camellia sinensis* extract (Black tea) in normal albino rats and those rendered hyperlipidemic by long term supplementation of fat-enriched diet. Albino rats of both sexes were used and grouped into seven groups; each consists of ten animals with different treatments. Blood samples were taken for biochemical analysis on days 30, 45 and 60 of the experiment. Iced black tea significantly decreased the elevated serum lipid parameters including total lipid, triglycerides, cholesterol, LDL-C, VLDL-C concentrations of rats fed on fat-enriched diet. However, it insignificantly affected their values in serum of negative control rats. In addition, iced black tea significantly increased the serum HDL-C concentration of rats fed on fat-enriched diet with insignificant changes in their values in serum of negative control rats. Administration of iced black tea to normal rats caused insignificant changes in serum liver enzymes concentration all over the period of the experiment; yet, it significantly decreased their elevated serum concentration in animals fed on fat-enriched diet compared to the +ve untreated ones, upon its administration starting from the day 30th of the experiment. These data suggest that iced *Camellia sinensis* extract has a good health impact in cases associated with hyperlipidemia

Keywords: *Camellia sinensis*; iced black tea; antihyperlipidemic

Introduction

Hyperlipidemia, particularly hypercholesterolemia is a major cause of atherosclerosis and atherosclerosis-associated conditions including coronary heart disease, ischemic cerebrovascular disease and peripheral vascular disease (Hardman and Limbird, 2001). The therape-

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utic target in such conditions is to lower blood and tissue levels of cholesterol and lipids. Currently available antihyperlipidemic drugs are always associated with some side effects such as gastric irritation, nausea, diarrhea, hyperuricemia, myositis, flushing, dry skin and abnormal liver function (Kumar et al., 2008). Nutriceuticals or nutrients with health impacts constitute, therefore, a considerable area of interest in minds of patients, physicians and researchers because of their safety and availability.

Teas are among drinks having health potentials at different aspects and its importance comes from its use on a daily basis by the young and the old in all countries (Fujita et al., 2000 and Fujita et al., 2001). *Camellia sinensis* extract (Black tea) contains major groups of active principles including theaflavins, thearubigins, catechins, flavones and others. Although some reports showed a relationship among some types of tea and some lipid parameters including cholesterol where some studies showed an apparent protective role against cardiovascular disease or stroke with high intakes of black tea or flavonoids (Keli et al., 1996 and Geleijnse et al., 1999) as well as the susceptibility of LDL to oxidation (Ishikawa et al., 1997); yet, there is no full information regarding the effect of iced black tea on hyperlipidemia and associated organ dysfunction. Therefore, the aim of this present study was to assess the hyperlipidemia improving profile of ice black tea as a nutriceutical approach to hyperlipidemia in rats rendered hyperlipidemic by long term feeding on high fat diet.

Material and methods

Iced Black tea (Camellia sinensis) extract

The black tea (BT) used in the present study was produced by Unilever Mashreq Company, Borg El-Arab, Egypt, under the commercial name Lipton®. It is used as bags containing 2.0 gm of a fine powdered tea. The major components of BT are theaflavins and thearubigins, the oxidation products of quinines and flavols (lin et al., 1998 & lee et al., 1989). Cold tea was prepared according to the method modified after Venditti et al., (2009) by placing 2 g of black tea powder in 10 ml of distilled water at room temperature with gentle agitation for 2 hours under magnetic stirring then filtering through Whatman papers (43-38 μm). The prepared tea filtrate was kept in the refrigerator until administration and was prepared freshly every day. BT was administered to rats at dosage rate of 0.55 g/kg b. wt rats daily (Chaudhuri et al., 2005) adjusted so that each rat receives 0.5 ml of BT aqueous solution orally using a rat gastric tube to the corresponding groups as will be explained later.

Chemicals

Atorvastatin (an inhibitor of cholesterol synthesis) used in the present study was produced by E.P.I.C.O (Egyptian Pharmaceutical International Company), 10th of Ramadan City, Egypt, under the commercial name ATOR®. It is presented as tablets containing 10, 20 and 40 mg of the drug. Atorvastatin was suspended in distilled water (0.66 mg/ml; 10mg tablet in 15 ml) and each rat was administered 0.5 ml of the prepared suspension daily using a gastric tube. This amount is equivalent to the dosage rate of 1.8 mg/kg. body weight daily (converted from human dose after Paget and Barnes, 1964) to the corresponding groups explained later. Ezetimibe **(**EZE, an inhibitor of cholesterol absorption) used in the present study was a kind gift from SIGMA pharmaceuticals, Quesna, Egypt. It was obtained as a

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pure powder. EZE was dissolved in 20% ethanol; where 10 mg of EZE were dissolved firstly in 5 ml absolute alcohol, and then the alcoholic EZE solution was completed to 25 ml by distilled water. Each rat within the target group received 0.5 ml of the prepared solution which is equivalent to a dosage rate of 1 mg/kg. body weight, orally, once daily (Patel, 2004).

Animals

Seventy albino rats of both sexes aging 6 weeks of approximate weights 180-200 g were used in this study. Rats were kept in separate cages and allowed to a plenty of water and diets at room temperature. After one week of acclimatization, rats received different treatments as Group I (Rats were fed on normal diet and received no drugs; kept as negative control), Group II (Rats were fed on fat-enriched diet and received no drugs; kept as positive control for all experimental groups), Group III (Rats were fed on normal diet and received iced black tea after 30 days from the start of the experiment; kept as negative treated group), Group IV (Rats were fed on fat-enriched diet and received ice black tea after 30 days from the start of the experiment; kept as positive treated group), Group V (Rats were fed on fat-enriched diet and received ice black tea from the start of the experiment; kept as concurrent treatment group), Group VI (Rats were fed on fat-enriched diet and received atorvastatin after 30 days from the start of the experiment; kept as a standard treated group), and Group VII (Rats were fed on fat-enriched diet and received EZE after 30 days from the start of the experiment; kept as standard treated group).

Sampling

Blood for serum was collected on the 30^{th}, 45^{th} and 60^{th} days from the start of the experiment. Samples were collected from the venous plexus located at the medial canthus of the eye by means of heparinized capillary tubes. The collected blood was allowed to clot at room temperature for an hour; and then refrigerated for further an hour for clot retraction. Clear sera were separated by centrifugation at 3000 r.p.m. for 10 minutes and then collected in Eppendrof's tubes using automatic pipettes. Serum samples were kept in deep freezer (-20 °C) for analysis of the biochemical parameters, which includes Total lipids (TL), total cholesterol (TC), triglycerides (TGs), high density lipoprotein-cholesterol (HDL-C), low density lipoprotein-cholesterol (LDL-C), very low density lipoprotein-cholesterol (VLDL-C), aspartate amino transferase (AST; SGOT), alanine amino transferase (ALT; SGPT), urea and creatinine.

Biochemical analysis

The serum total lipids were determined according to the method described by Chaboral (1961) using a kit supplied by SPINREACT, Sant Esteve De Bas, Spain; total cholesterol was determined enzymatically according to the method described by Meiattini (1978) using a kit supplied by SPINREACT; HDL-L was determined according to the precipitation method described by Friedewald et al., (1972) using a kit supplied by SPECTRUM, Obour city, Egypt; TGs were determined enzymatically according to the method described by Young and Pestaner (1975) using a kit SPINREACT. LDL-C and VLDL-C values were

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Table 1. Effect of iced BT on serum total lipids. Effect of oral administration of 0.5 ml BT solution (equivalent to 0.55g/kg b.wt) daily for 60 days on serum total lipids concentration (Ẍ ± S.E; mg/dl) in albino rats fed on basal and fat-enriched diets (n=10).

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
Day 30	319.42 ±15.22	680.86* ±20.13	411.66 ±28.00	627.33 ±23.00	572.33 ±28.82	630.22 ±25.45	650.04 ±15.61
Day 45	347.55 ±23.11	690.43* ±23.77	398.00 ±29.23	547.66¤* ±24.00	448.33¤* ±52.83	480.09¤ ±29.38	575.45¤ ±30.23
Day 60	369.11 ±25.25	704.5* ±21.60	357.33 ±10.92	510.66¤* ±26.84	433.00¤* ±23.77	450.65¤ ±14.44	532.25¤ ±25.33

Group I: -ve control
Group II: +ve control
Group III: -ve treated with BT
Group IV: +ve treated with BT
Group V: +ve treated plus BT
Group Vi: +ve treated with Ator
Group VII: +ve treated with EZE
*= (p<0.05) wrt –ve control
¤= (p<0.05) wrt +ve control

calculated using the formulae described by Fridewald et al., (1972) and Bauer (1982), respectively. Serum AST and ALT were quantitatively determined according to the method described by Murray (1984) using kits supplied by DIAMOND, Cairo, Egypt. Urea was quantitatively determined according to the method described by Kaplan (1984) using a kit supplied by DIAMOND, Cairo, Egypt; while creatinine was quantitatively determined according to the method described by Murray (1984) using a kit supplied by the same company.

Statistical analysis

Data were expressed as mean±S.E which are calculated using a SigmaPlot® software. The obtained data were statistically analyzed using Student's *t*–test to express the differences between groups according to Snedecor and Cokran (1980).

Results

Effect of iced BT on serum lipid profile

As shown in table 1,2,3,,5,6, there were significant increases in serum total lipid, cholesterol, triglycerides, LDL-C, VLDL-C concentrations in rats fed on fat-enriched diet, compared to rats received basal diet. While administration of iced BT to normal rats caused insignificant changes in these parameters all over the period of the experiment; yet, its

Table 2: Effect of iced BT on serum cholesterol. Effect of oral administration of 0.5 ml BT solution (equivalent to 0.55 g /kg b.wt) daily for 60 days on serum cholesterol concentration (Ẍ ± S.E; mg/dl) in albino rats fed on basal and fat-enriched diets (n=10).

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
Day 30	70.57 ±5.60	139.58* ±8.06	76.45 ±5.11	140.03 ±8.33	130.11 ±8.75	145.00* ±5.36	135.33 ±8.40
Day 45	73.50 ±4.03	160.75* ±8.06	73.50 ±4.80	125.21¤ ±7.30	115.21¤ ±4.16	98.33¤ ±7.00	125.33¤ ±14.40
Day 60	77.60 ±9.34	168.55* ±14.69	68.91 ±10.48	108.11¤ ±7.97	100.22 ¤ ±6.80	92.33¤ ±7.00	117.34¤ ±10.35

Group I: -ve control
Group II: +ve control
Group III: -ve treated with BT
Group IV: +ve treated with BT
Group V: +ve treated plus BT
Group Vi: +ve treated with Ator
Group VII: +ve treated with EZE
*= (p<0.05) wrt –ve control
¤= (p<0.05) wrt +ve control

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Table 3. Effect of iced BT on serum TG. Effect of oral administration of 0.5 ml BT solution (equivalent to 0.55 g/kg b.wt) daily for 60 days on serum TGs concentration (Ẍ ±S.E; mg/dl) in albino rats fed on basal and fat-enriched diets (n=10).

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
Day 30	89.75 ±11.94	196.38* ±17.99	86.11 ±3.60	180.55 ±4.70	165.98 ±9.06	187.75* ±4.09	176.66 ±24.53
Day 45	91.5 ±5.67	188.62* ±14.86	90.12 ±5.10	140.11¤ ±4.32	125.33¤ ±8.06	87.66¤ ±5.92	166.49 ±9.64
Day 60	84.99 ±7.13	185.30* ±16.99	88.28 ±4.11	120.33¤ ±4.24	104.12¤ ±10.11	74.99¤ ±4.81	154.16¤ ±10.48

Table 4. Effect of iced BT on serum HDL-C. Effect of oral administration of 0.5 ml BT solution (equivalent to 0.55 g /kg b.wt) daily for 60 days on serum HDL-C concentration (Ẍ±S.E; mg/dl) in albino rats fed on basal and fat-enriched diets (n=10).

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
Day 30	40.85 ±3.35	22.32* ±2.66	37.03 ±1.27	21.89 ±3.48	17.53 ±1.27	16.13* ±3.67	17.46* ±1.49
Day 45	42.15 ±4.18	19.24* ±2.58	40.09 ±1.80	25.98 ±1.77	27.76 ±2.44	35.33¤ ±4.63	25.54 ±1.04
Day 60	41.73 ±1.81	15.33* ±2.62	42.11 ±1.80	33.16 ±2.14	35.97 ±1.49	38.12* ±1.80	31.62* ±1.80

Table 5: Effect of iced BT on serum LDL-C. Effect of oral administration of 0.5 ml BT solution (equivalent to 0.55g/kg b.wt) daily for 60 days on serum LDL-C concentration (Ẍ ±S.E; mg/dl) in albino rats fed on basal and fat-enriched diets (n=10).

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
Day 30	10.03 ±1.6	61.38* ±3.38	14.11 ±1.36	64.79 ±5.85	57.01 ±6.00	59.16* ±7.81	61.66* ±7.33
Day 45	11.86 ±1.31	77.05* ±5.70	23.11 ±1.45	52.11¤ ±3.11	49.35¤ ±7.36	40.33¤ ±5.63	57.17¤ ±7.13
Day 60	16.11 ±1.13	81.14* ±9.02	30.11 ±1.23	47.10¤ ±4.24	42.89¤ ±8.15	35.55¤ ±7.14	52.91¤ ±9.05

Table 6. Effect of ice BT on serum VLDL-C. Effect of oral administration of 0.5 ml BT solution (equivalent to 0.55 g/kg b.wt) daily for 60 days on serum VLDL-C concentration (Ẍ ±S.E; mg/dl) in albino rats fed on basal and fat-enriched diets (n=10).

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
Day 30	24.4 ±1.90	34.52* ±2.13	25.55 ±2.13	34.99 ±2.01	31.33 ±2.28	35.75* ±1.30	36.83* ±5.74
Day 45	21.58 ±1.88	35.38* ±2.41	22.13 ±1.59	31.01 ±2.33	28.50 ±2.39	29.86¤ ±1.20	35.21 ±1.91
Day 60	22.66 ±2.00	37.94* ±2.20	18.99 ±2.86	29.12 ±3.67	25.31¤ ±3.58	24.99¤ ±0.96	31.1¤ ±4.64

Group I: -ve control
Group II: +ve control
Group III: -ve treated with BT
Group IV: +ve treated with BT
Group V: +ve treated plus BT
Group Vi: +ve treated with Ator
Group VII: +ve treated with EZE
*= (p<0.05) wrt –ve control
¤= (p<0.05) wrt +ve control

administration significantly decreased their serum levels in rats fed on fat-enriched diet. On the other hand, as shown in table 4, there was a significant decrease in rats kept on high-fat

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Table 7. Effect of ice BT on serum VLDL-C. Effect of oral administration of 0.5 ml BT solution (equivalent to 0.55 g/kg b.wt) daily for 60 days on serum VLDL-C concentration (Ẍ ±S.E; mg/dl) in albino rats fed on basal and fat-enriched diets (n=10).

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
Day 30	14.32 ±2.09	25.75* ±1.25	16.11 ±1.15	26.78 ±1.25	24.13 ±1.00	28.76* ±1.33	26.53* ±1.44
Day 45	16.34 ±1.60	27.75* ±2.13	16.02 ±1.33	25.11 ±1.15	21.03 ±1.84	23.36¤ ±1.33	23.65 ±2.17
Day 60	15.2 ±1.82	26.75* ±1.86	14.21 ±1.46	23.66 ±2.75	20.01¤ ±1.66	21.61¤ ±1.33	22.73 ±3.66

Group I: -ve control
Group II: +ve control
Group III: -ve treated with BT
Group IV: +ve treated with BT
Group V: +ve treated plus BT
Group Vi: +ve treated with Ator
Group VII: +ve treated with EZE
*= (p<0.05) wrt –ve control
¤= (p<0.05) wrt +ve control

Table 8. Effect of iced BT on serum SGOT (AST). Effect of oral administration of 0.5 ml BT solution (equivalent to 0.55 g/kg b.wt) daily for 60 days on serum SGOT (AST) concentration (Ẍ±S.E; U/L) in albino rats fed on basal and fat-enriched diets (n=10).

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
Day 30	23.11 ±2.30	38.25* ±2.39	22.50 ±0.86	37.70 ±5.22	33.50 ±2.59	40.50 ±2.98	39.25 ±2.39
Day 45	21.25 ±5.32	39.00* ±4.07	20.90 ±2.39	34.75 ±4.11	32.33 ±3.06	32.5 ±2.98	35.80 ±1.63
Day 60	22.70 ±2.53	37.50* ±4.38	21.01 ±4.11	30.12 ±1.90	29.25¤ ±2.39	28.5¤ ±2.98	32.66 ±4.09

Group I: -ve control
Group II: +ve control
Group III: -ve treated with BT
Group IV: +ve treated with BT
Group V: +ve treated plus BT
Group Vi: +ve treated with Ator
Group VII: +ve treated with EZE
*= (p<0.05) wrt –ve control
¤= (p<0.05) wrt +ve control

diet. Such decrease was significantly improved upon administration of iced BT. Again, there was no significant changes in rats kept on basal diet.

Effect of iced BT on Liver function profile

Data of the present study (tables 7 and 8) demonstrate a significant increase in serum ALT and AST concentrations of rats fed on fat-enriched diet all over the two-month period of the experiment, compared to the control rats that received basal diet. Although administration of iced BT to normal rats caused insignificant changes in serum liver enzymes concentration all over the period of the experiment; yet, it significantly decreased their elevated serum concentrations in animals fed on fat-enriched diet compared to the +ve untreated ones, upon its administration starting from the day 30th of the experiment.

Effect of iced BT on kidney function profile

Data of the present study (tables 9 & 10) demonstrate a significant increase in serum urea and creatinine concentrations of rats fed on fat-enriched diet allover the two-month period of the experiment, compared to the control rats that received basal diet. Although administration of iced BT to normal rats caused insignificant changes in serum urea and creatinine concentrations all over the period of the experiment; yet, it significantly decreased their elevated serum concentrations in animals fed on fat-enriched diet compared to the +ve untreated ones, upon its administration starting from the day 30th of the experiment. Howe-

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Table 9. Effect of iced BT on serum urea. Effect of oral administration of 0.5 ml BT solution (equivalent to 0.55 g/kg b.wt) daily for 60 days on serum urea concentration (X̄ ±S.E; mg/dl) in albino rats fed on basal and fat-enriched diets (n=10).

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
Day 30	41.50 ±2.80	55.97* ±2.99	40.01 ±1.85	57.47* ±3.32	51.62 ±3.80	61.75* ±2.00	59.04* ±1.40
Day 45	43.00 ±1.88	58.68* ±1.30	39.20 ±1.04	50.56¤ ±1.40	47.49 ±2.41	49.33¤ ±1.40	54.25 ±2.00
Day 60	42.50 ±2.34	57.04* ±2.00	37.22* ±2.26	45.56¤ ±1.42	46.19¤ ±1.04	46.04¤ ±1.40	49.90 ±1.98

Group I: -ve control
Group II: +ve control
Group III: -ve treated with BT
Group IV: +ve treated with BT
Group V: +ve treated plus BT
Group Vi: +ve treated with Ator
Group VII: +ve treated with EZE
*= (p<0.05) wrt –ve control
¤= (p<0.05) wrt +ve control

Table 10. Effect of iced BT on serum creatinine. Effect of oral administration of 0.5 ml BT solution (equivalent to 0.55 g/kg b.wt) daily for 60 days on serum creatinine concentration (X̄ ±S.E; mg/dl) in albino rats fed on basal and fat-enriched diets (n=10).

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7
Day 30	1.10 ±0.17	1.80* ±0.18	1.25 ±0.12	1.75 ±0.09	1.66 ±0.08	1.95 ±0.11	2.05 ±0.05
Day 45	1.23 ±0.08	1.98* ±0.12	1.31 ±0.17	1.60 ±0.09	1.45 ±0.09	1.40 ±0.10	1.86 ±0.11
Day 60	1.20 ±0.18	2.10* ±0.18	1.30 ±0.12	1.53¤ ±0.14	1.30¤ ±0.05	1.35¤ ±0.17	1.66 ±0.06

Group I: -ve control
Group II: +ve control
Group III: -ve treated with BT
Group IV: +ve treated with BT
Group V: +ve treated plus BT
Group Vi: +ve treated with Ator
Group VII: +ve treated with EZE
*= (p<0.05) wrt –ve control
¤= (p<0.05) wrt +ve control

ever, concurrent administration of iced BT with high fat diet from the beginning failed to guard against the rise of serum urea and creatinine.

Discussion

Lipids and lipid metabolism are involved in almost all biological activities inside the normal subjects. Thus, that is well established, alteration in lipid metabolic profile especially long standing hyperlipidemia is a direct cause to various disease conditions including atherosclerosis, ischemic heart disease (Emara, 1999). Neyyir (2002) supported this fact by reporting that the problem of hyperlipoproteinemia is being of much interest nowadays because an elevated concentration of lipoproteins can also accelerate the development of atherosclerosis with a dual sequel of thrombosis and cardiac infarction. In addition, triacylglycerols and cholesterol are important biological lipids, and their excessive intake in the diet is related to the development of two prevalent cardiovascular risk factors, obesity and hyper-cholesterolemia (Ros, 2000).

Data of the present study revealed that hyperlipidemia, induced by continuous supplementation of high fat (coconut oil 2% wt/wt) and high cholesterol (1% wt/wt) diet, caused marked alterations (mainly increase except HDL-C which is decreased) in almost all lipid parameters of rat groups fed on such diet. Moreover, the obtained hyperlipidemia was associated with elevated markers for some organ dysfunction as liver, kidneys, heart and aorta together with considerable histopathological changes in these organs (data not shown). These findings

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led us to use such rats as a model for hyperlipidemia to assess the possible antihyperlipidemic role of iced black tea that is a popular drink liked by almost all people all over the world.

Data of the present study (table 1) demonstrate a significant increase in serum total lipid concentration of rats fed on fat-enriched diet all over the two-month period of the experiment, compared to the control rats that received basal diet. This result of hyperlipidemia is consistent to that have been reported previously in more then one species including, rats by Csont et al., (2002), rabbits by Diaz et al., (2000) and Hellal (1997); and laying hens by Hammad (2002).

Although administration of iced BT to normal rats caused insignificant changes in serum total lipids concentration all over the period of the experiment; yet, it significantly decreased serum total lipid concentration in animals fed on fat-enriched diet compared to the +ve untreated ones, upon its administration starting from the day 30^{th} of the experiment, i.e. after the induction of hyperlipidemia. The decrease in serum total lipid concentration in BT-treated animals may be logic after recording the decreased levels of serum triglycerides, total cholesterol, LDL-C and VLDL-C that were observed simultaneously in this study. This result is consistent with that reported by Ramadan et al., (2009) who found that the BT as well as the green tea extracts significantly decrease plasma total lipid concentration in alloxan-diabetic and cholestereol-fed rats. Ramadan and colleagues attributed such effect of BT extract to its polyphenol content. Biochemical and pharmacological evidence gave the mechanisms by which polyphenols contained in BT prevent obesity and decrease total lipid. These include stimulating hepatic lipid metabolism from one hand; and inhibiting fatty acid synthase from the other hand (Lin and Lin-Shiau, 2006).

Data of the present study (table 2) demonstrate a significant increase in serum total cholesterol concentration of rats fed on fat-enriched diet all over the two-month period of the experiment, compared to the control rats that received basal diet. This result is consistent with those achieved by Diaz et al., (2000) who reported that, rabbits fed with the atherogenic diet showed marked increase in plasma total cholesterol. The result is also consistent with that of Abdel-Maksod et al., (2002) who reported that mice and rats received cholesterol-enriched diet showed sever hypercholesterolemia, elevated plasma serum LDL-C and VLDL-C compared to those fed a normal diet. In addition, Hammad (2002) reported that, administration of laying hens with diet rich in cholesterol diet led to marked elevation in plasma total cholesterol.

Rise in serum cholesterol might be attributed to the reduced catabolic rate of serum TC or reduced activity of hepatic cholesterol-7-alpha-hydroxylase, the rate limiting enzyme in bile acid synthesis from cholesterol (Abdel-Maksod et al., (2002). Moreover, the rise in serum TC observed in this study could be attributed to increased HMG-CoA reductase activity in the liver of animals fed on fat-enriched diet and the reduced rate of the clearance of LDL from circulation due to defective LDL receptors which associated with increase of plasma TC concentration (Zulet et al., 1999). Histopathological examination of aortic specimens dissected from hyperlipidemic rats in this study revealed focal subintimal lesion showing degenerative areas in the vessel wall. This result may be consistent with that obtained by De La Cruz, et al., (2000) who reported that rabbits are susceptible to the development of atherosclerosis, where keeping them on high cholesterol diet resulted in alterations in typical ather-

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osclerotic changes in the aorta. Similarly, Yoshie, et al., (2004) stated that rabbits with high serum cholesterol concentrations developed intimal lesions similar to those of human atherosclerosis. Although administration of iced BT to normal rats caused insignificant rise in serum total cholesterol concentration all over the period of the experiment; yet, it signific-antly decreased serum cholesterol concentration in animals fed on fat-enriched diet compared to the +ve untreated ones, upon its administration starting from the day 30th of the experime-nt. The hypocholesterolemic effect of iced BT may be explained on the basis of increasing the transfer of blood cholesterol to be used in bile synthesis and thus, biliary excretion of cholesterol or bile acids is increased resulting in reduced availability of cholesterol to be incorporated into lipoproteins (An et al., 1997).

Data of the present study demonstrated in table 3 show a significant increase in triglycerides in animals kept on fat-enriched diet compared to their corresponding control. This result may be in accordance with those recorded by Margaret, et al., (2000), who found that a hyperlipidemic diet caused a significant increase of the plasma triacylglycerols and an increased content of cholesterol in the liver, despite the fact that the diet produced a cessation of endogenous cholesterol synthesis. Such significant rise in serum triacylglycerols level may be attributed to the decrease of activity of lipase which is an insulin-dependent enzyme involved in triglyceride clearance from plasma by mediating triglyceride lipolysis into glyce-rol and FFA (Yost et al., 1995). Another possibility is that such significant increase in triglycerides might be a consequence of over production of VLDL by the liver. Daily oral administration of iced BT significantly decreased serum TG concentration in animals fed on fat-enriched diet compared to the +ve untreated ones, without any significant effect in TG concentration in animals kept on basal diet. This data may be consistent with that of Yang et al., (2001) who reported that BT as well as green and oolong tea extracts reduce TG concentration in rats rendered hyperlipidemic by feeding on high sucrose diet. They attributed this effect to that BT may decrease feed efficiency while green tea may decrease feed absorption. Our data may be also in accordance with Hakim et al., (2003) who reported that increased consumption of BT is associated with decreased TG concentration in serum of Saudi women. The significant decrease in plasma TG was explained previously by Bennani-Kabchi et al., (2000) who related them to the increased rate of lipolysis that is mediated by increase of plasma lipase activity. However, Griffin et al., (1982) stated that the low plasma TG concentration might also reflect the low rate of hepatic lipogenesis or the use of plasma TG by tissues other than adipose ones.

Data obtained in the present study that demonstrated in tables 4,5 and 6 revealed significant increases in serum LDL-C and VLDL-C and a significant decrease in HDL-C in the group of rats that was fed on fat-enriched diet all over the period of the experiment, compared to the corresponding control group. These results are in accordance with those reported by Abdel-Maksod et al., (2002), who reported that mice and rats receiving cholesterol-enriched diet showed sever elevated plasma LDL-C and VLDL-C compared to those kept on a normal diet. Hussein and colleagues concluded that the elevated serum LDL-C and VLDL-C seemed to be related mainly to reduced catabolic rate that occurs when the production of LDL exceeds the capacity of LDL receptors present on hepatocytes; in other words when the efflux of cholesterol from the liver becomes more than its influx. Mahley and Habcombe (1977) stated that both dietary fat and cholesterol may change the lipoprotein content of ser-

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um and affect the different classes of lipoproteins, LDL and HDL and increases the content of cholesterol in VLDL.

Analysis of samples taken on the days 45 and 60 in the present study, have shown that iced BT administration revealed significant decreases in serum LDL-C and VLDL-C concentrations and a significant increase in HDL-C if compared to the rats which were fed fat-enriched diet. The improving effect of green tea as well as BT may be mediated, probably, by decreasing the apo-B which is the principal protein that comprises nearly 90% of total protein mass of LDL (Ramadan et al., 2009). In addition, it may be speculated that BT may increase the preipheral and hepatic breakdown of cholesterol esters from VLDL and LDL. While the compositional change of HDL also suggests activation of Lecithin-cholesterol acyltransferase (LCAT) which must be stimulated firstly by exogenous cholesterol.

Data of the present study (tables 7 and 8) demonstrate a significant increase in serum ALT and AST concentrations of rats fed on fat-enriched diet all over the two-month period of the experiment, compared to the control rats that received basal diet. Although administration of iced BT to normal rats caused insignificant changes in serum liver enzymes concentrtration all over the period of the experiment; yet, it significantly decreased serum their concentration in animals fed on fat-enriched diet compared to the +ve untreated ones, upon its administration starting from the day 30^{th} of the experiment. These data may be consistent with Fujita et al., (2008) who found that BT intake in hypercholesterolemic subjects elicits significant antihypercholesterolemic effect along with decreased ALT and AST levels compared to the subjects who received corresponding *placebo*. The authors attributed this effect to the enhancing effect of BT on cholesterol hepatic metabolism as well as inhibiting its intestinal reabsorption. Similar results were reported by Ramadan et al., (2009) who reported beneficial effects of BT, that is rich in theaflavins and thearubujins, and green tea, that is rich in catechins, on both ALT and AST activities as well as other parameters in two rat models, namely, alloxan-induced hyperglycemia, hyperlipidemia and liver dysfunction; and cholesterol-rich diet-induced hyperlipidemia.

Finally, regarding renal function, iced BT treatment significantly decreased serum urea and creatinine concentrations which were elevated upon continuous high-fat diet (tables 9 and 10). Such rise might be attributed to the nephritic changes occurred in the renal tissue upon fat, especially cholesterol, administration. These changes might be ameliorated upon BT administration due its cholesterol lowering and renal artery dilating effects. This data suggest that BT may have an antihyperlipidemic effect and, thus, may have a good health impact in hyperlipidemia and associated conditions.

Conflict of interest

There is no conflict of competing interest associated with the authors of this paper.

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