Round Black, Long White Eggplant Diets for Clinical Nutrition of Fructose Induced Hypertensiona, Hyperglycemia and Hyperlipidemia

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ABSTRACT

The aim of the present study was to evaluate some potential therapeutic effects of peel and pulp of two eggplant varieties (round black and long white) which are widely consumed among Egyptian people using experimental rats. Peel and pulp samples were analyzed to determine the chemical composition and some minerals (Na, K and Fe). Total phenols content also were determined in addition to the identification of phenolic compounds by HPLC. The dried peel and pulp of two eggplant varieties were supplemented as 15% to the diet and used for treating diabetic, hypertensive, and hyperlipidemic rat. Thirty male albino rats weighing 140±10 g were divided to 6 groups (5 rats in each group). Five groups were given 10% fructose in the drinking water for 6 weeks to induce hypertension, hyperlipidemia and hyperinsulinemia. At the end of the experiment, Serum glucose, insulin, total cholesterol, triglycerides, lipoprotein fractions, blood pressure, serum Na, K, and MDA levels were determined in rats serum. In addition the kidney and liver of rats were removed after ether anaesthetesia and making histopathological examination. Briefly, different tested eggplant types can be considered as a good healthy food which can prevent and improve the status of hyperglycemia, hyperlipidemia, and hypertension. Peel of round black eggplant was more effective for lowering hyperlipidemia and hypertension and improved lipid profile, while the long white type was more effective for lowering hyperglycemia. These healthy effects of eggplant can be attributed to its good content of fibers, phenolic compounds, and potassium. Furthermore, the eggplant has the ability to bind with bile acids and inhibiting the activity of some enzymes as α-glucosidase and angiotensin converting the enzyme which increases hypertension.

Key words: Eggplant (peel and pulp), Phenolic compounds, Diabetes, Hypertension, Hyperlipidemia.

INTRODUCTION

Nowadays, chronic diseases and their long term complications are widely spread. Medications become costly and have many side effects.Therefore, many studies have been carried out aiming to decrease these problems or search for new alternatives such as natural sources. Phytotherapy is called medicinal plants or herbs which are defined as substances that prevent and treat different diseases by using plants, parts of plant and preparations made from them (Weiss and Fintelmann,2000). Healthy and unhealthy people must consume fruits and vegetables regularly, which contain nutrients like vitamins, minerals, and non nutritive constituents as fiber and phenolic compounds. These components are associated with reduced risk of developing chronic diseases such as cardiovascular disease (CVD), cancer, diabetes and delayed vital functions disorders with age (Yeh and Yen , 2005 and Temple et al., 2006).

Many vegetables belonging to the Solanaceae family as potato, tomato, chili pepper, and eggplant are important for their richness in healthy components and are widely consumed (Helmja et al., 2007). Eggplant *(Solanummelongena)* is a common vegetable grown and consumed all around the world.It varies in color, size, and shape according to eggplant cultivar (Nishaet al., 2009 and Singh et al., 2009). The greatest production of eggplant is coming from five countries; China and India are the first and second countries which produce 56% and 26% of world output, respectively. The production of Egypt, Turkey and Indonesia from eggplant is equal (FAO, 2014).

Eggplant contains many bioactive constituents that have healthy effects, for example flavonoids, minerals, vitamins, and other products which possess several medicinal properties as revealed by Nisha et al., (2009). It has also a high content of fiber and low in fat and energy (Kala and Prakash, 2006; Kahlon et al., 2007[a]; and Zevnik, 2009),in addition to high mineral content with K being the principal element and moderate amounts of Ca, P , and Mn as reported by Ejoh et al.,(1996). Furthermore, eggplant contains ascorbic acid and polyphenols which are powerful antioxidants (Helmja et al., 2007; Nishaet al., 2009). Oxidative stress resulting from excessive free-radical release and/or decrease in the antioxidant defense systems can cause damage in the proteins, DNA, and lipids which lead to increased risk of cancer and CVD. The consumption of sufficient amounts of antioxidants is important to prevent or slow down the oxidative stress (Temple et al., 2006). Meanwhile, eggplant is ranked among the top ten vegetables for the free radical scavenging activity (Nisha et al., 2009).

Eggplant extract has good effects on diabetes and hypertension. This extract has α–glucosidase and angiotensin converting enzyme (ACE) having inhibitory activities which provide a basis for management of type 2 diabetes by controlling glucose absorption associated with reducing hypertension (Kwon et al., 2008). The results about the eggplant or its components which affect lipid metabolism are controversial.Some studies showed beneficial effects of reducing the hypercholesterolemia in animals (Huang et al., 2004; and Kahlon et al., 2007[-a]) whileother studies did not support this hypothesis (Praca et al., 2004 and Silva et al., 2004).Hence, still there is a need for more studies about the role of eggplant in reducing of the hypercholesterolemia, diabetes mellitus, and hypertension. For this reason, the present study aimes to investigate the role of a variety of eggplant kinds and their components in treating the diabetic and hyperlipidemic rats along with hypertension.

MATERIALS AND METHODS

MATERIALS

All chemicals and solvents used in minerals determination were HPLC grade. Standard phenolic compounds were obtained from sigma (St . Louis, USA) and from Merck-Schuchardt (Munich, Germany).

Commercially available kits were purchased from (Alkan Medical Company, St. El-Doky, Cairo, Egypt). All other chemicals were obtained from El-Gomhoria Company, Cairo, Egypt.

Eggplant.

Round Black Eggplant (RBE) and Long White Eggplant (LWE) aretwo different types of eggplant (*Solanummelongena* , L.), free of blemishes or obvious defects, were purchased from the local market (Shiben El-Kom, Menofia, Egypt) .

Each kind of the eggplant was cleaned and separated to peel and pulp which were immersed immediately in 0.1% citric acid solution for 1-2 min before drying. Drying process was done in the National Central Research, Unit of Sunny Energy, Cairo, Egypt. The dried peel and pulp were ground in an electric mill and passed through 80 mesh sieves (British standard screen). The fine powder was kept in glass containers and stored at -20 °C until used.

Animals

Thirty adult male albino rats, with average weight ranged between 140 ± 10 g were obtained from Helwan Experimental Animals Station, Egypt. Under the normal laboratory conditions, the rats were housed in cylindrical wire cages with wire bottoms. Rats were fed on a basal diet for a week as an adaptation period.The diet was introduced to the rats in special food cups to avoid scattering of the food. Also, the water was provided to the rats by glass tube projection through the wire cage. Food and water were provided and checked daily. The rats were fed on normal diet according to AIN-93 guidelines (Reeves et al., 1993).

Methods

Chemical composition

Moisture, crude protein, fat, total ash, and fiber were determined as described in the A.O.A.C. procedures (2012). Total carbohydrates were estimated by difference on dry matter basis as follows:

% Carbohydrates = 100 - (% protein + % fat +% fiber + % Ash).

Estimation of minerals content (Na, K and Fe) in dried samples were carried out by putting samples in muffle furnace at 550 °C until white ash.Then the ashwas dissolved in 0.1N HCL and analysed using Atomic Absorption Spectrophotometer (Perkin – Elmer instrument Model 2380).

Identification of phenolic compounds by HPLC

A known weight of the dried powdered sample was soaked in 25 ml sterilized water and removed on a rotary shaker for 24 h. The aqueous extract was filtered through whatman 3 MM filter paper under vacuum, followed by centrifugation at 10000rpm for 30 min at 80°C. Phosphoric acid was used to acidify an aqueous extract to pH 2.5. Each sample was partitioned three times with an equal volume of diethyl ether. The layer of diethyl ether was evaporated to dryness under low pressure at 30°C. The resulting residue was dissolved in 3 ml of spectral grade methanol and filtered through a 0.2 mm filter sterilized membrane prior to HPLC analysis.

Identification of individual phenolic compounds of the eggplant samples was performed on a Hewlett-Packard HPLC (Model 1100), using C18 reversed-phase column (250 × 4.6 mm) with 5 mm particle size. A constant flow rate (1 ml / min) was used with two mobile phases: (A) 0.5 % acetic acid in distilled water at pH 2.65, and solvent (B) 0.5 % acetic acid in 99.5 % acetonitrile. The gradient of elution was starting with mobile phase A and ending with mobile phase B during 35 min, using an UV detector set at wavelength 254 nm. The relative retention times were used to identify the phenolic compounds in each sample comparing with standard mixture of phenolic compounds. The concentration of an individual compound was calculated on the basis of peak area measurements, then converted to mg phenolic acid/100 dry weight.

Biological experiment.

Preparation of Hypertensive, Hyperlipidemic and Hyperinsulinemic rats.

Hypertension was induced in rats (140 ± 10 g) by adding 10% fructose (w/v) in the drinking water for 6 weeks. Fructose solution was prepared every day and given to the rats throughout the whole experimental period (Dimo et al., 2002 and Mohan et al., 2009). The drinking water with fructose for one week or longer is appropriate to induce hypertension in rats. Moreover, consumption of fructose is associated with elevated levels of plasma insulin, glucose, and triglycerides according to Dai and McNeill, (2001); Li et al., (2006) and Olatunji et al., (2005).

Experimental design and animal groups

Thirty rats were randomly divided into six groups (5 rats each). Group one was reserved as a normal control which received the basal diet and water. Group two was kept as a positive control which received 10% fructose in drinking the water and fed on basal diet. Groups from three to six received 10% fructose in drinking the water (Mohan et al., 2009)and fed on a basal diet containing 15% RBE peel, RBE pulp, LWE peel and LWE pulp respectively.

Blood Pressure measurements.

Systolic blood pressure (SBP), diastolic blood pressure (mm Hg) and pulse rate were measured by Non Invasive Blood Pressure Recorder, Indirect, Rat (Model 58500, UGO Basile, Switzerland) in Faculty of El-Kasr El-Aini Medicine, Pharmacology Department.

Blood sampling

At the end of experimental period, all rats were fasted overnight. After that, the rats were scarified under ether anaesthetesia and blood samples were collected in clean centrifuge tube from the hepatic portal vein. Serum samples were obtained by centrifugation of the blood (4000 rpm for 10 min) at room temperature. Then, the serum was kept in a plastic vial and stored frozen at -20^{0}C until analysis (Schermer, 1967).At the same time, kidney and heart were removed, cleaned, and stored in 10% formallin solution for histopathological examination according to the method mentioned by Drury and Wallington (1980).

Biochemical assays.

Kits were used to calculate serum levels of glucose, Insulin, triglycerides, total cholesterol, total lipids, and HDL-cholesterol according to the manufacturer's instructions. The determination of VLDL (very low density lipoproteins) and LDL (low density lipoproteins) were carried out according to the equation of Lee and Nieman (1996) as follows:

VLDL (mg/dl) = Triglycerdes/5

LDL (mg/dl) = Total cholesterol – (HDL + VLDL)

Lipid peroxide was determined by estimated Malondialdehyde (MDA) concentration according to a modified published method by Ohkawa et al., (1979). The technique was used to detect the concentration of Na and K was carried out using atomic absorption spectrometry (AAS) technique equipped with burner (PyeUnicam, model 929) as described by Jorhem (2000).

Histopathological Investigation:

Small specimens from the kidneys and heart were collected from all the experimental groups, fixed in neutral buffered formalin, dehydrated in ascending concentration of ethanol (70, 80, and 90%), cleared in xylene, and embedded in paraffin. Sections of (4-6) μm thickness were prepared and stained with Hematoxylin and Eosin according to (Bancroft et al., 1996).

Statistical analysis

The results were analyzed using SPSS for Windows (Version 10.0) statistical software and expressed as Mean ± standard deviation .Analysis of variance between groups was performed using one-way ANOVA test followed by Duncan's multiple range test at a significance level of $P \leq 0.05$.

RESULTS AND DISCUSSION

Chemical composition

The chemical composition of peel and pulp for (RBE) and (LWE) are presented in table (1). Generally, the moisture, fat, protein, and carbohydrates contents in the pulp were higher than the peel. The pulp of both (RBE) and (LWE) were higher in the contents of moisture, fat, protein, and carbohydrates than those in the peel. While the ash , fiber, and total phenols contents were higher in the peel than in the pulp of both kinds of eggplant. These results are in agreement with those reported by Ejoh et al., (1996) Asaolu and Asaolu (2002); Huang et al., (2004) and Kahlon et al., (2007[a]).

The different eggplant types and parts have considerable amount of potassium (K). The highest value was recorded in (LWE) peel (2387 mg/100 g DW) while the lowest level was noticed in (RBE) pulp (2016 mg/100 g DW). The same trend was observed exactly in Na. The levels of iron (Fe) were 6.7, 5.7, 7.1, and 5.8 mg/100g DW. Generally, eggplant peel contained K, Na and Fe more than the pulp.

According to Asaolu and Asaolu(2002),in both cooked and uncooked eggplant varieties, the minerals contentswere higher in the coat than in the flesh and sodium (Na) and potassium (K) were found to be the highest contents followed by phosphorus (P) in both the coat and the flesh. The authors also reported thateggplant in the diet along with eating raw fruits would be more beneficial than the cooked ones.

In addition, Kala and Prakash (2006) showed that the content of Ca, P, and Fe were 242, 338, and 6.12 mg/100g on DW respectively. Also, Raigon et al., (2008) reported that eggplant provides relevant quantities of P,K, and Cu to the diet, with global mean values of 26.6, 198.5, and 0.062 mg/100g of fresh weight, respectively.

Table 1: The chemical composition, total phenols, Na, K, and Fe in the peel and pulp of the two types of eggplant basis (on dry weight basis)

Parameters	(RBE)		(LWE)	
	Peel	Pulp	Peel	Pulp
	M ± SD	M ± SD	M ± SD	M ± SD
Basic components(g/100g)				
Moisture	90.3 ± 0.115	93.0 ± 0.255	88.4 ± 0.435	91.6 ± 0.128
Ash	7.60 ± 0.091	7.30 ± 0.198	8.70 ± 0.041	8.31 ± 0.127
Fat	1.40 ± 0.062	1.90 ± 0.310	1.38 ± 0.105	2.30 ± 0.185
Protein	8.10 ± 0.015	9.20 ± 0.102	8.90 ± 0.310	9.91 ± 0.041
Carbohydrate	52.6 ± 0.128	57.5 ± 0.064	44.2 ± 0.055	56.7 ± 0.085
Fiber	30.3 ± 0.020	24.1 ± 0.030	36.8 ± 0.085	22.8 ± 0.041
Total phenols	4.15 ± 0.450	3.65 ± 0.150	3.42 ± 0.120	2.77 ± 0.140
Minerals (mg/100 g)				
Na	128 ± 4.23	115 ± 2.15	149 ± 7.45	131 ± 5.48
K	2134 ± 5.60	2016 ± 2.36	2387 ± 4.55	2301 ± 3.56
Fe	6.7 ± 0.05	5.7 ± 0.09	7.1 ± 0.03	5.8 ± 0.03

Each value in the table is the Mean ± Standard Deviation of three replicates.

Phenolic compounds

Phenols composition fractions are presented in table (2). The results show wide differences between the peel and pulp of eggplant. Pyrogallic acid and orthocoumaric acid were two of three compounds which were detected in large quantities in (RBE) peel and (LWE) pulp. Values of these compounds were 7.225 and 16.742 mg/100 g DW for (RBE) peel and 0.689 and 52.905 mg/100 g DW for (LWE) pulp respectively. There are five compounds which were found in both the (RBE) pulp and (LWE) peel. These compounds were arranged in a descending order as follows coumarin, cinnamic acid, paracoumaric acid , pyrogallic acid and gallic acid. Small amounts of protocatechuic acid, catechin and para hydroxyl benzoic acid were detected in (LWE) peel but not appeared in (RBE) pulp. Vice versa, phenol and orthocoumaric acid were detected in (RBE) pulp but did not appear in (LWE) peel. Phenol was observed in round black pulp only at level 0.158 mg/100g DW. In general, the highest identified phenolic compounds were observed for coumarin, ortho coumaric acid then cinnamic and paracoumaric acids.

Eggplant contains a high amount of polyphenols which are considered the main component of non enzymatic antioxidant defense system and that has a high capacity to catch free radicals and protect the body against increasing ROS. Yeh and Yen (2005) noticed that asparagus, broccoli, and eggplant had relatively higher amounts of total phenolic content compared to the other twenty studied vegetables. The total phenolics content of eggplant was 4.8 mg/g fresh weight (FW) and contained trace amount of gallic acid, P-hydroxybenzoic acid, and gentisic acid, while P-coumaric acid in eggplant was 1733 μg/g FW, which was the highest compared to its content in broccoli (1306 μg/g FW) and asparagus (183 μg/g FW). In addition to, the total phenolic content of eggplant skin is about two times greater than that in the eggplant pulp (Huang et al., 2004). The same results were confirmed by Helmja et al., (2007) who pointed to the eggplant skin extract which had the highest total phenolic and flavoniod contents 1.5 g/L (900 mg/100g) and 1.1 g/L (600 mg/100g), respectively compared to these in the vegetables of Solanoceae family (tomato, chilli pepper, and potato).The polyphenols found in skin extract of eggplant are phenolic acids (chlorogenic acid, cinnamic acid, caffeic acid, and ferulic acid).Generally it is important to notice that the extracts of vegatables such as eggplant are very complex in the composition and the determination of individual compound requires the use of several analytical methods. A high number of flavonols and flavones conjugates and isomers are present in the plant extract and may also be present as glycoside .The references to these compounds are rarely available, thus it is difficult to determine all the components present in plant matrices. This also may be the reason for undetected important compounds in the peel of round black eggplant which may be present in other conjugates, isomers or glycosides forms that required specific extract preparations , references or analytical methods [Helmja et al., (2007) and Helmja et al., (2009)].

Glucose and Insulin level

Data from table (3) illustrate that a positive control group showed a significant ($p<0.05$) increase levels of fasting serum glucose and insulin being 158 ± 9.17 mg/dl and 16.7 ± 1.55 μU/ml, respectively as compared to the levels of normal control group which were 114.7 ± 9.27 mg/dl and 13.4 ± 0.75 μU/ml, respectively. Similar results were obtained by Mohan et al., (2009).

Table 2: Phenols composition estimated by HPLC analysis in the peel and pulp of the two eggplant types (mg / 100 g dry weight)

Phenolic compounds (mg/100g DW)	Retention time (min)	(RBE) Peel	(RBE) Pulp	(LWE) Peel	(LWE) Pulp
Pyrogallic acid	22.285	7.225	0.352	1.097	0.689
Gallic acid	23.673	-	0.078	0.055	-
Protocatechuic acid	29.503	2.063	-	0.270	-
Catechin	32.679	-	-	2.520	2.072
Para hydroxy benzoic acid	34.327	-	-	0.112	-
Para coumaric acid	38.495	-	6.378	2.457	-
Phenol	40.038	-	0.158	-	-
Ortho coumaric acid	42.178	16.742	0.545	-	52.905
Salicylic acid	44.876	-	-	-	-
Coumarin	47.457	-	46.626	47.288	-
Quercetin	48.458	-	-	-	-
Cinnamic acid	51.915	-	10.082	11.782	-

Each value in the table is the Mean of two replicates.

Table 3: Effect of dried peel and pulp of two eggplant types at 15% of diet for 6 weeks on fasting serum glucose and insulin in fructose induced hypertensive, hyperlipidemic, hyperinsulinemic rats

Parameters \ Groups	Normal Control	Positive Control	F + 15 % (RBE) Peel	F + 15 % (RBE) Pulp	F + 15 % (LWE) Peel	F + 15 % (LWE) Pulp	LSD
Glucose (mg/dl)	$114.7^{b} \pm 9.27$	$158^{a} \pm 9.17$	$125^{b} \pm 11.27$	$130^{b} \pm 8.67$	$118^{b} \pm 10.58$	$114^{b} \pm 7.94$	17.93
Insulin (µU/ml)	$13.4^{b} \pm 0.75$	$16.7^{a} \pm 1.55$	$14.2^{b} \pm 1.01$	$13.9^{b} \pm 0.95$	$14.5^{b} \pm 0.78$	$14.9^{ab} \pm 1.37$	2.085

Data are expressed as mean ± SD. Values within a row having different superscripts are significantly different ($p \leq 0.05$); where the small letters indicate significant among dietary treatment groups as indicated by one-way ANOVA followed by Duncan's multiple range test (a > b > c > d > e).
F = Fructose as 10% of drinking water.

Also, the researches that used a high fructose diet (as approximately 60%) for various duration showed a number of adverse metabolic effects such as hyperglycemia, hyperinsulinemia, hypertriglyceridemia, impaired glucose tolerance, impaired insulin sensitivity and oxidative stress. All different groups which were treated with different parts of eggplant showed the same effect and no significant ($p>0.05$) differences were found in reducing the glucose and insulin levels compared with a normal control group. The role of eggplant parts in reduction of glucose level and the improvement of insulin sensitivity may be related to eggplant contents. Eggplant has a high fiber and low soluble carbohydrate content which are important for improved glycemic control by reducing the glycemic load and affecting the absorption of glucose (Biliaderis and Izydorczyk, 2007). Also, eggplant contains a considerable amount of potassium which is a commonly principal mineral used to control blood glucose level by reducing insulin resistance (Watson and Preedy, 2008). In addition to, eggplant extracts are enriched with total phenols, and arehighing in α-glucosidase, moderate to low α-amylase inhibitory activity, moderate to high angiotensin I-converting enzyme (ACE) inhibitory activity. Inhibition of these enzymes provides a strong biochemical basis for management of type 2 diabetes by controlling glucose absorption, starch breakdown, and reducing hypertension (Kwon et al., 2008).

Lipid profile

Results in table (4) showed the elevating of T.L, T.G and MDA in rats which received 10 % fructose in drinking water. Groups fed on different eggplant parts showed significant reduction T.L ($p<0.05$) than positive control group but in the same time, the previous groups did not show significant reduction of T.L level compared with normal control group.

T.G level was greatly increased due to fructose treatment from 46.8 ± 5.96 mg/dl in normal control group to 96.3 ± 10.02 mg/dl in positive control group. The (RBE) peel and pulp presented no significant ($p>0.05$) differences among them compared with normal control group. On the other hand, the peel and pulp of (LWE) had the same effect in reduction of T.G level, but both of them showed significant ($p<0.05$) differences in decreasing of T.G level against healthy group.This result is in agreement with Sudheesh et al., *(*1999*)* findings.

Also, from the same table (4) it can be noticed that MDA was raised significantly from 1.3 ± 0.1 nmol/ml in normal rats to 1.7 ± 0.1 nmol/ml in control positive rats, MDA levels for all eggplant treatments showed no significant (p>0.05) differences among each other and also as compared with healthy rats.

Table (5) exhibits the parameters of total cholesterol (TC) in the serum of rats. These results showed that feeding with different eggplant diets combined with fructose treatment corrected significantly (p<0.05) TC elevation. The best treatments of T.C reduction were (RBE) pulp& (RBE) peel, and (LWE) pulp diets which recorded 84.7 ± 6.02, 86.3 ± 1.53 and 88.3 ± 9.02 mg/dl respectively. All groups treated with eggplant parts were of no significant differences (p>0.05) between each other and also compared with normal control group except (RBE) pulp.

Results of HDLc level from the same table (5) indicated that different eggplant treatments showed significant (p<0.05) increase in HDLc which almost reached the HDLc level of normal control group. Moreover, HDLc level of (LWE) peel group (56 ± 4.58 mg/dl) was numerically higher than that of the healthy group. No significant (p>0.05) differences of HDL level were observed between (RBE) peel, (RBE) pulp and (LWE) pulp or between these groups and normal control group.

All eggplant treatments achieved significant (p<0.05) reduction of LDLc as compared to the positive control group, but did not reach to a significant level from healthy group. There were no significant differences between different eggplant diets, while the best LDLc reduction recorded for (RBE) peel then (LWE) peel & pulp of eggplant diet.

As regard to VLDLc, feeding different eggplant diets showed significant (p<0.05) decreases for VLDLc as compared to the positive control group. VLDLc level of (RBE) pulp and peel diets showed no significant (p>0.05) differences between each other and also compared to healthy group. Also, the same result was showed in (LWE) peel and pulp.

Several researchers pointed to the consumption of 10% fructose in drinking water for 6 weeks which induced significant hypertriglyceridemia as reported by Giani et al., (2009), and Mohan et al., (2009) and hypercholesterolemia Dimo et al., (2002) and Mohan et al., (2009). No significant changes for LDLc, HDLc, and LDLc/HDLC ratio were observed by (Olatunji and Soladoye, 2007); and oxidative stress (Olatunji and Soladoye, 2007,

Table 4: Effect of dried peel and pulp of twoeggplant types at 15% of diet for 6 weeks on total lipids (T.L), triglycerides (TG) and malodialdehyde (MDA) in fructose induced hypertensive, hyperlipidemic, hyperinsulinemic rats.

Groups / Parameters	Normal Control	Positive Control	F + 15 % (RBE)		F + 15 % (LWE)		LSD
			Peel	Pulp	Peel	Pulp	
T.Lipids (mg/dl)	$266^{d} \pm 22.91$	$458^{a} \pm 12$	$319.5^{c} \pm 36.8$	$376^{b} \pm 9.17$	$400^{b} \pm 10$	$399.5^{b} \pm 16$	36.93
TG (mg/dl)	$46.8^{c} \pm 5.96$	$96.3^{a} \pm 10.02$	$50^{c} \pm 5.57$	$48^{c} \pm 2$	$65.3^{b} \pm 6.51$	$64.3^{b} \pm 7.02$	11.26
MDA (nmol/ml)	$1.3^{b} \pm 0.1$	$1.7^{a} \pm 0.1$	$1.4^{b} \pm 0.17$	$1.4^{ab} \pm 0.09$	$1.5a^{b} \pm 0.09$	$1.4^{b} \pm 0.13$	0.224

Data are expressed as mean ± SD. Values within a row having different superscripts are significantly different (p ≤ 0.05); where the small letters indicate significant among dietary treatment groups as indicated by one-way ANOVA followed by Duncan's multiple range test (a > b > c > d > e).
F = Fructose as 10% of drinking water.

Table 5: Effect of dried peel and pulp of two eggplant types at 15% of diet for 6 weeks on TC, HDLc, LDLc and VLDLc in fructose induced hypertensive, hyperlipidemic, hyperinsulinemic rats.

Groups / Parameters	Normal Control	Positive Control	F + 15 % (RBE)		F + 15 % (LWE)		LSD
			Peel	Pulp	Peel	Pulp	
TC (mg/dl)	$80.8^{c} \pm 5.14$	105.4 $^{a}\pm 6.59$	$86.3^{bc} \pm 1.53$	$84.7^{c} \pm 6.02$	$95.5^{b} \pm 4.82$	$88.3^{bc} \pm 8.02$	9.633
HDLc (mg/dl)	$50.8^{ab} \pm 3.42$	$34.5^{c} \pm 3$	$50.7^{ab} \pm 2.38$	$46.7^{b} \pm 4.93$	$56^{a} \pm 4.58$	$48.6^{b} \pm 4.16$	6.996
LDLc (mg/dl)	$20.71^{c} \pm 1.11$	$51.66^{a} \pm 3.71$	$25.63^{b} \pm 1.46$	$28.43^{b} \pm 2.77$	$26.43^{b} \pm 1.59$	$26.8^{b} \pm 2.69$	4.640
VLDLc (mg/dl)	$9.36^{c} \pm 1.19$	$19.26^{a} \pm 2$	$10^{c} \pm 1.11$	$9.61^{c} \pm 0.40$	$13.07^{b} \pm 1.3$	$12.87^{b} \pm 1.4$	2.253

Data are expressed as mean ± SD. Values within a row having different superscripts are significantly different (p ≤ 0.05); where the small letters indicate significant among dietary treatment groups as indicated by one-way ANOVA followed by Duncan's multiple range test (a > b > c > d > e).
F = Fructose as 10% of drinking water.

and Reddy et al., 2009). On the other hand, Olatunji et al., (2005) showed that diet containing (25%) fructose resulted in significant increases in plasma glucose, total cholesterol, triglycerides, TC/HDL-c ratio and malondialdehyde.

Malondialdehyde is a reliable marker of lipid peroxidation and oxidative stress. Also the authors discussed these adverse effects as commonly associated with diabetes and are known to be high-risk factors for development of cardiovascular diseases as indicated by Manzella et al., (2001).

On the present study, rats treated with 15% dried eggplant parts showed a significant reduction of T.L, TG, TC, LDLc, LDLc, MDA, and increased HDLc levels. The reports by different researches about the effect of eggplant or its components on lipid metabolism are controversial.

The effect of eggplant and its parts as hypolipidemia may be due to some different compounds such as eggplant flavonoids extract which showed a significant reduction of cholesterol, TG level, liver and kidney phospholipids, and serum and liver free fatty acids (Sudheesh et al., 1997).As well as Sudheesh et al., *(1999)* found that eggplant flavonoid extract decreased levels of MDA, hydroperoxides, conjugated dienes, and rate of lipid peroxidation in healthy rats and rats fed on fat. Also, a significant increase in antiperoxidative enzyme catalase was observed. So, a diet containing moderate amount of eggplant flavonoids may reduce risk of cardiovascular disease.

Moreover, dietary fiber in eggplant reduced cholesterol by binding bile acids and use of built cholesterol to synthesize bile acid. So, these properties are related to the lowering risk of heart disease (Kahlon et al., 2007[-a] and Kahlonet al., 2007[-b]). In addition to, the percent of cholesterol reduction in experimental animals and human by soluble fiber reached to 5 - 15% and the amount of fiber needed for this is 15-30 g/day(Guimaraes et al., 2000). Eggplant skin inhibit at least 90% of LDL peroxidation (Huang et al., 2004); this result come in parallel to that suggested by Cherem et al., (2007) about the use of eggplant core in humans to reduce TC and LDLc although HDLc reduction occurred.

Anthocyanin is another compound which is found in eggplant peel and has more beneficial effects as free radicals scavenger and in chelating excess iron and protects the body against lipid peroxidation (Noda et al., 2000; and Zevink, 2009).

Furthermore, specific components such as phytosterols and saponins which are found in eggplant may show beneficial effects. Saponins are a group of glycosides that stimulate the heart. 150 mg/kg saponinsinin the diet is enough to increase the fecal excretion of bile salts in animals & humans and reducing TC without affecting HDLc (Guimaraes et al., 2000).

Phytosterols are steroid compounds similar to cholesterol which occur in plants and vary only in carbon side chains. Total sterol content of the eggplant was 7mg/100g in the edible portion (Spiller, 1996) and 1-3 g plant sterols/day achieved approximately 5% LDLc reduction (Biliaderis and Izydorczyk, 2007).

Blood Pressure parameters

Data from table (6) illustrate that a positive control group showed a significant ($p<0.05$) elevation of SBP and DBP compared with other groups and recorded 156 ± 11 and 95 ± 7 mmHg respectively. All groups treated with eggplant parts were showed a great difference between them in reduction of SBP. The maximum correction of SBP compared to positive control group was recorded by (RBE) peel diet (121 ± 12 mmHg) and the minimum effect was recorded in (LWE) pulp group (149.7 ± 15.1 mmHg). The decrease in SBP level of peel was higher than that of the pulp for each eggplant type. Reductions in DBP level by feeding rats on different eggplant diets did not reveal any significant changes between each other and also as compared to normal group. As regard to pulse rate (PR) and serum Na results, there were no significant ($p>0.05$) differences between all groups.

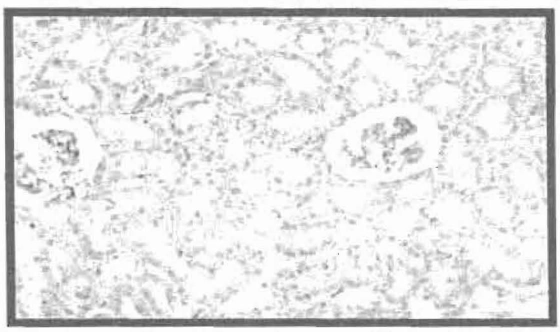
A positive control group showed a negligible decrease of serum K level than a normal control group (3.7 ± 0.3 and 3.8 ± 0.2 mmol/l respectively). In addition, the rats fed on different eggplant diets showed a significant ($p<0.05$) increase of serum K level. On the other hand, peel and pulp of each eggplant type showed no significant difference among each other.

The consumption of 10% fructose in the drinking water for one week or longer is appropriate for the rapid elevation of hypertension in rats according to Dai and McNeill, (2001); Dimo et al., (2002) and Mohan et al., (2009).The same result was noticed by Sanchez-Lozada et al., (2007) who said that the administration of fructose either in diet (60%) or drinking water (10%) induced hypertension. Fructose induced hypertension is not directly associated with Na retention. Similar results were observed by LyerandKatovich (1996) who documented that hypertension induced by fructose in rats does not occur directly via sodium retention or by an increase in fluid volume. While, others as Singh et al., (1996) suggested that fructose induced hypertension by increasing salt absorption via the intestine and kidney. The mechanism of hypertension by fructose feeding includes sodium retention and fluid volume expansion, stimulation of the sympathetic nervous system and vascular small muscle proliferation, and increase in cytosolic Ca^{2+}(Dimo et al., 2002).

Table 6: Effect of dried peel and pulp of two eggplant types at 15% of diet for 6 weeks on Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP), Pulse Rate, serum sodium (S.Na) and serum potassium (S.K) in fructose induced hypertensive, hyperlipidemic, hyperinsulinemic rats

Groups / Parameters	Normal Control	Positive Control	F + 15 % (RBE)		F + 15 % (LWE)		LSD
			Peel	Pulp	Peel	Pulp	
SBP (mmHg)	$98^{F} \pm 6$	$156^{a} \pm 11$	$121^{e} \pm 12$	$127^{d} \pm 10.54$	$139^{c} \pm 10$	$149^{b} \pm 15.1$	5.488
DBP (mmHg)	$80^{b} \pm 5.57$	$95^{a} \pm 7$	$79^{b} \pm 5$	$79^{b} \pm 4$	$83^{b} \pm 6$	$85^{b} \pm 6$	8.773
Pulse Rate (beat/min)	$387^{a} \pm 36$	$410^{a} \pm 37.40$	$412^{a} \pm 34.77$	$413^{a} \pm 40.63$	$418^{a} \pm 42.5$	$426^{a} \pm 39.15$	57.59
S. Na (mmol/L)	$131^{a} \pm 2.65$	$129^{a} \pm 4$	$132^{a} \pm 6.56$	$131.7^{a} \pm 3.56$	$131.3^{a} \pm 2.08$	$130.75^{a} \pm 6.9$	9.149
S. K (mmol/L)	$3.8^{bc} \pm 0.2$	$3.7^{c} \pm 0.3$	$4.23^{b} \pm 0.2$	$4.2^{b} \pm 0.25$	$5.1^{a} \pm 0.27$	$4.8^{a} \pm 0.27$	0.462

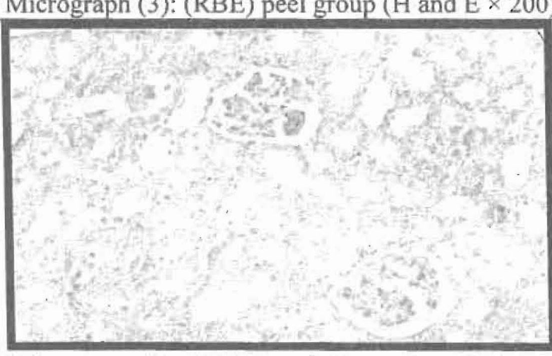
Data are expressed as mean ± SD. Values within a row having different superscripts are significantly different ($p \leq 0.05$); where the small letters indicate significant among dietary treatment groups as indicated by one-way ANOVA followed by Duncan's multiple range test (a > b > c > d > e).
F = Fructose as 10% of drinking water.


Micrograph (1) Normal group (H and E × 200)


Micrograph (2) Positive group (H and E × 200)

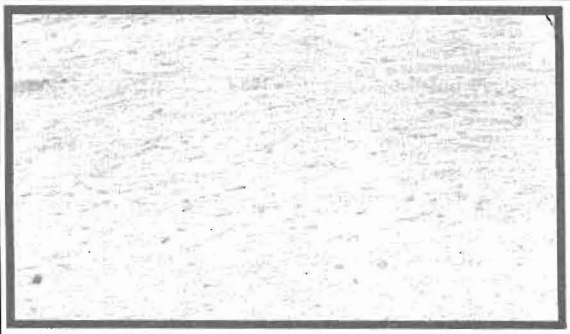

Micrograph (3): (RBE) peel group (H and E × 200)


Micrograph (4): (RBE) pulp group (H and E × 200)


Micrograph (5): (LWE) peel (H and E × 200)

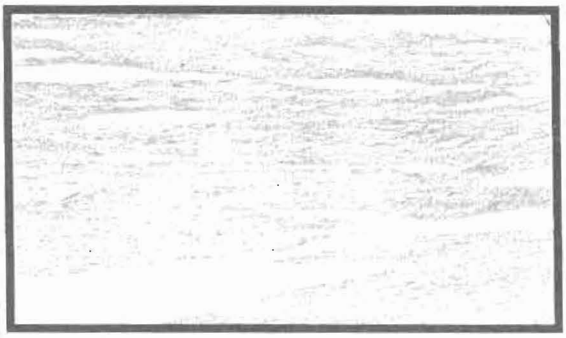

Micrograph (6): (LWE) pulp group (H and E × 200)

Figure 1: Kidneys of rats from normal, positive, (RBE) peel, (RBE) pulp,(LWE) peel and (LWE) pulp groups.



Micrograph (7) Normal group (H and E × 200)

Micrograph (8) Positive group (H and E × 200)



Micrograph (9): (RBE) peel group (H and E × 200)

Micrograph (10): (RBE) pulp group (H and E × 200)

Micrograph (11): (LWE) peel (H and E × 200)

Micrograph (12): (LWE) pulp group (H and E × 200)

Figure 2: Heart of rats from normal, positive, (RBE) peel, (RBE) pulp,(LWE) peel and (LWE) pulp groups.

Moreover, researches as Lyer and Katovich (1996) suggested that renin-angiotensin system plays a role in the development of fructose-induced hypertension. Anywise, the mechanism of fructose induced hypertension remains under investigation and unclear. The diet of rats containing 15 % dried eggplant parts was effective to prevent or lower hypertension caused by fructose loading and the best effect was recorded for (RBE) peel then its pulp as shown from the results.This seemed to agree with Duke et al., (2002). Angiotensin I-Converting Enzyme (ACE) is another active enzyme which is involved in maintaining the vascular tension. ACE activates angiotensin I into a potent vasoconstrictor called angiotensin II which stimulates the synthesis and release of aldosterone and increase blood pressure by promoting sodium retention. Eggplant had angiotensin converting enzyme (ACE) inhibitory activities and inhibition of ACE is considered a useful therapeutic approach in the treatment of hypertension in both diabetic and non-diabetic persons (kwon et al., 2008). Furthermore, antihypertensive agents that inhibit the ACE may improve insulin sensitivity and prevention of type 2 diabetes, and atherosclerotic cardiovascular diseases (Kurtz and Pravence, 2004 and Kurtz, 2006). Potassium is another factor used to reduce blood pressure. Intake of foods rich in potassium has the same effect on reduction of blood pressure like taking potassium chloride (Feng et al., 2005); but balance between Na and K will be kept close to 1 for maintaining arterial homeostasis (Temple et al., 2006; Kappor and Kappor, 2009).

Histopathological examination

1-Kidneys

Microscopically, kidneys of the rat from the healthy group revealed the normal histopathological structure of renal parenchyma (Micrograph 1). However, kidneys of positive group revealed vacuolation of epithelial lining renal tubules associated with eosinophilic cast in the lumen (Micrograph 2). Kidneys of fructose treated rat combined with feeding on (RBE) peel diet revealed slight distension of Bowmen's space (Micrograph 3). Congestion of intertubular blood vessels was the only change observed in kidneys of rat form group of (RBE) pulp (Micrograph 4). However, kidneys of rat treated by fructose combined with feeding on (LWE) peel diet revealed no histopathological changes (Micrograph 5). Kidneys of rat from group of (LWE) pulp showed vacuolations of epithelial lining in some renal tubules and endothelial lining of glomerular tuft (Micrograph 6).

Heart

Microscopically, heart of rat form healthy group revealed normal cardiac myocytes (Micrograph 7). Examined heart of fructose treated rat from control (+) group showed vacuolations of sarcoplasm of cardiac myocytes and focal myocarditis (Micrograph 8). Heart of rats form groups of fructose treated rats combined with feeding on (RBE) peel and pulp diets revealed no histopathological changes (Micrograph, 9, 10). Slight intramuscular edema was noticed in heart of rat from group of (LWE) peel (Micrograph 11). Also, heart of rat form group of (LWE) pulp showed intramuscular edema (Micrograph 12).

CONCLUSION

Different tested eggplant types can be considered as good healthy foods which can prevent and improve the status of hyperglycemia, hyperlipidemia, and hypertension. Round black eggplant especially the peel was more effective for lowering hyperlipidemia and hypertension in addition to improve lipid profile, while the long white type was more effective for lowering hyperglycemia. These healthy effects of eggplant can be attributed to its chemical composition (by good deal of fibers, phenolic antioxidants, and potassium, this in addition to its low content of soluble carbohydrates, fat, and hence low calories value); and some important physiological effects as showed by some researches as bile acids- binding capacity, and inhibition activity of enzymes as α-glucosidase and angiotensin converting enzyme. Mineral content (Na and K) of eggplant especially the long white type which has the highest level of it, should be considered to be balanced and among total mineral content of the diet reaching to the highest benefits without unfavorable effects. Anywise, further specific researches are needed to prove and detect the mechanism of eggplant action toward these respects.

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الملخص العربى

وجبات الباذنجان الأسود المستدير والأبيض الطويل للتغذية العلاجية لارتفاع ضغط الدم وارتفاع سكر الدم وارتفاع دهون الدم المحدث بواسطة الفركتوز

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تهدف الدراسة الحالية إلى تقييم بعض التأثيرات العلاجية الفعالة لكلا من قشر ولب نوعين من الباذنجان (الباذنجان الأسود المستدير والأبيض الطويل) والذي ينتشر استهلاكهما بدرجة كبيرة بين أفراد الشعب المصري. وقد تم تحليل كلاً من القشر واللب لمعرفة التركيب الكيماوي وتقدير بعض المعادن كالصوديوم والبوتاسيوم والحديد. كما تم أيضا التعرف على المركبات الفينولية بواسطة جهاز التحليل الكرموتجرافى ذو السائل عالي لأداء(HPLC). تم إضافة كلا من القشر واللب المجفف إلى غذاء الفئران بنسبة ١٥% لعلاج الفئران المصابة بارتفاع السكري وضغط الدم ودهون الدم. من اجل ذلك تم تقسيم ٣٠ فأر ذكر زنة ١٤٠ جرام إلى ٦ مجموعات(٥ فئران بكل مجموعة)، وتناولت ٥ مجموعات منها ١٠% من سكر الفركتوز المضاف إلى ماء الشرب لمدة ٦ أسابيع لكي يحدث ارتفاعا في مستوى ضغط الدم والإنسولين والدهون الكلية. وفى نهاية التجربة تم قياس كلا من مستوى الجلوكوز والإنسولين والكولسترول والليبوبروتينات وضغط الدم ومستوى البوتاسيوم والصوديوم وكذلك نسبة المالونالدهيد فى سيرم الفئران. بالإضافة إلى ذلك فقد تم إزالة كلا من الكبد والكلى بعد عملية التخدير وفحصهم هستوباثولوجيا. وقد أظهرت النتائج أن الباذنجان يعد من الأغذية الصحية التي تستطيع أن تمنع أو تقلل من ارتفاع الجلوكوز والإنسولين وضغط الدم ودهون الدم. وقد أظهر قشر الباذنجان الأسود المستدير فاعلية أكبر من غيره في خفض دهون الدم وعلاج ضغط الدم وتحسين مستوى الدهون الكلية بينما كان الباذنجان الأبيض أكثر فائدة في خفض نسبة السكري. وترجع هذه التأثيرات الصحية للباذنجان إلى احتواؤه على كميات مناسبة من الألياف والمركبات الفينولية وعنصر البوتاسيوم بالإضافة إلى قدرته على ربط أملاح الصفراء وتثبيط نشاط بعض الإنزيمات مثل الفا جلكوزيديز وإنزيم تحويل الانجيوتنسين الذي يزيد من ضغط الدم.

الكلمات الدليلية: الباذنجان(القشرة واللب)، المركبات الفينولية، السكري، ضغط الدم، وارتفاع دهون الدم.