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Antidiabetes Effect of Aqueous Extract of leaves Lemongrass (*Cymbopogon citratus*) and its Leaves Powder on Diabetic Rats

Mohamed M. El-Sayed, Mai M. Khafagy, Amina M. Ratib
Dept. of Nutrition and Food Sciences, Faculty of Home Economics, Menoufia University, Shibin El Kom, Egypt.

Abstract
This study was conducted to investigate the effect of lemongrass aqueous leaves extract and powder on glucose levels of injected rats with alloxan. Thirty white male albino rats, weighing 150±10g BW. each, were used in this study and divided into 6 equal groups. each group contain 5 rats, one was kept as a control negative group while the other groups were injected by alloxan (150 mg/kg body weight). The treated with lemongrass aqueous leaves extract and powder were given as a percentage of 1% and 2% of lemongrass aqueous leaves extract, 2.5% and 5% of lemongrass leaves powder from the Basel diet. At the end of the experiment, glucose levels, serum liver function (AST, ALP and ALT), kidney functions (urea, creatinine and uric acid), total cholesterol (TC), triglycerides (TG), high density lipoprotein (HDL-c) low density lipoprotein (LDL-c) and very low density lipoprotein (VIDL-c) were assessed. The results indicated that tests plants improved glucose levels, liver functions, kidney functions and lipid profile. According to these results, moderate amounts of lemongrass leaves in our diets could be used for improvement glucose level.

Keywords: Blood glucose levels, Lipid Profile, biochemical analysis, liver functions

Introduction:
Diabetes mellitus (DM) is the most common form of diabetes patients caused by a lack of the hormone insulin level or increased in insulin resistance, which leads to hyperglycemia (Rang *et al*., 2015). Diabetes mellitus is a global burden, which affects about 1 in 11 individuals all over the world (Papademetriou *et al*., 2019).
Moreover, some reports have shown that nearly a third of the world's population will develop diabetes by the year 2050 (Dyer et al., 2019).

According to the World Health Organization (WHO) statistics and a study conducted by Danaei et al., (2011) who reported that there were 347 million people with diabetes. While the disease is prevalent in first world countries, the prevalence of the disease is expected to increase from 3.8% to 4.3% in Africa by 2030 (Unwin et al., 2012).

The International Diabetes Federation (IDF) listed Egypt among the world top 10 countries in the number of patients with diabetes. It is expected that the number of patients with diabetes in the Middle East and North Africa (MENA) region to grow by 96% from year 2013 to 2035 or from 34.6 million to 67.9 million. In Egypt, the prevalence of diabetes is around 15.56% among adults between 20 and 79 years of age, with an annual death of 86,478 related to diabetes. In 2013, the IDF estimated that 7.5 million individuals have diabetes and around 2.2 million have prediabetes in Egypt. Furthermore, reports indicate that 43% of patients with diabetes and most patients with prediabetes in Egypt are likely undiagnosed. It is alarming that diabetes prevalence in Egypt has increased rapidly within a relatively short period from approximately 4.4 million in 2007 to 7.5 million in 2013. It is expected this number will jump up to 13.1 million by 2035(International Diabetes Federation (IDF),2013).

Type 1 diabetes is characterized by destruction of beta cells caused by an autoimmune process, which usually leads to absolute insulin deficiency. According to Kumar and Clark (2002) who indicated that type 1 diabetes is usually characterized by the presence of antiglutamic acid decarboxylase, islet cell or insulin antibodies that determine the autoimmune processes that lead to destruction of the beta cells. All type1 diabetic patients may need insulin therapy to maintain their blood sugar level (Baynes, 2015).

Lemongrass (Cymbopogon citratus) is one of the most common crops cultivated in tropical climates and is commonly used as a cooking herb or as an alternative herbal remedy in treating or preventing some diseases because it contains antibacterial, antifungal, antioxidant, antiseptic, anti-inflammatory, analgesic and antipyretic properties (Goyal and Ananad , 2013).

The genus Cymbopogon, commonly known as lemongrass, belongs to the Poaceae family. It originates from southwest Asia (southern India and Sri Lanka), but nowadays it grows spontaneously all over the world, especially in the tropical and subtropical regions (Machraoui et al., 2018).

Cymbopogon citratus is used in traditional medicine for the treatment of gastrointestinal disturbances, fevers and hypertension. It is commonly used in the form of tea as a

"homemade remedy" for cough, flu, gingivitis, digestive problems and stomachache (Avoseh et al., 2015).

Cymbopogon citratus Considered one of the most sourced plants in the world due to its distribution and use. Different extracts of C. citratus have shown various pharmacological properties. The antimicrobial, antiinflammatory, antidiabetic, and anticancer amongst others are well reported (Lawal et al., 2017).

The main target of this work is studying the effect of addition different concentrations (1% and 2 %) lemongrass aqueous leaves extract (2%and 5%) lemongrass leaves as powder on biological, biochemical and antidiabetic changes of male albino rats as antidiabetic.

Materials and Methods:

The used plants:

Lemongrass (Cymbopogon citratus) dry leaves were obtained from the Local Herbals Company, Tanta City,Gharbia Governorate , Egypt.

Alloxan powder:

Alloxan, it was pure chemical fine product (DBH) were purchased from SIGMA Chemical Co., (USA), and was used for induction of diabetes among rats.

Experimental animals (Rats):

A total of 30 adult normal male albino rats Sprague Dawley strain weighing 150 ±10 g were obtained from Vaccine and Immunity Organization, Ministry of Health, Helwan Farm, Cairo, Egypt. Rats were housed in wire cages under the normal laboratory condition and were fed on standard diet for a week as an adaptation period. Diet was offered to rats in special food cups to avoid looser conditions of food, water was provided to the rats by glass tubes supported to one side of the cage, food and water provided ad-labium and checked daily.

Methods:

Preparation of materials:

Lemongrass (Cymbopogon citratus) dry leaves were obtained from the local Herbals Company, Tanta City, Gharbia Governorate, Egypt.

Preparation of the extract:

Exactly 200g of the fine powder was soaked in 1000ml (IL) of distilled water in a conicalflask, the mixture allowed to stand on the laboratory bench for 30mins, there after shaken and boiled for l hour lt was then cooled and filtered (Garba et al ., 2020).

Experimental design:

Thirty adult male white albino rats, Sprague Dawley Strain, 10 weeks age, whighing (150 ±10g) were used in this experiment. The experimental was done in the Faculty of Home Economics, Menoufia University, Shebin El-kom. Rats were housed in wire cages in a room temperature 25 0C and kept under normal healthy conditions. All rats were fed on basal diet prepared according to American Institute of Nutrition (AIN), 1993) for 7 consecutive days. After this adaptation period, rats are divided into 6 groups, each group which consists of 5 rats as follows:

Group (1): Negative control group – normal group (5 rats) in this group rats were kept on standard diet and tap water.

Group (2): In this group, rats were induced by alloxan (150 mg/kg body weight), for a week to induce pancreas impaired according to the method described by Desai and Bhide, (1985). And fed on basal diet and used as a positive control group.

Group (3): A group injected diabetic was fed on basal diet and lemongrass leaves as powder by 2.5% of the weight of the diet.

Group (4): A group injected diabetic was fed on basal diet and lemongrass leaves as powder by 5% of the weight of the diet.

Group (5): A group injected diabetic was fed on basal diet and lemongrass leaves as aqueous extract by 1% of the weight of the diet.

Group (6): A group injected diabetic was fed on basal diet and lemongrass leaves as aqueous extract by 2% of the weight of the diet.

During the experimental period, the body weight and food intake were estimated weekly and the general behavior of rats was observed. The experiment will take 28 days, at the end of the experimental period each rat weight separately then, rats are slaughtered and collect blood samples. Blood samples were centrifuged at (4000 rpm) for ten minute to separate blood serum, then kept in deep freezer till using. Extracting the liver and kidney the following tests were conducted for histological examinations.

Biological evaluation:

Biological evaluation of the different diets were carried out by determination of body weight gain (BWG %), food efficiency ratio (F.E.R), according to Chapman et al., (1959). Using the following formulas:

$$\text{B.W.G.} = \frac{(\textbf{Final weight} - \textbf{Initial weight}) \times 100}{\textbf{Initial weight}}$$

$$\text{F.E.R.} = \frac{\textbf{Gain in body weight (g)}}{\textbf{Feed intake (g)}}$$

Relative organs weight:

At the same time, The different organs of rats (heart, kidney, liver, lungs, spleen and stomach) were carefully removed, washed in saline solution, dried between 2 filter papers and immediately weighted then the (liver and kidney) kept in buffered formalin solution (10%) for histopathological examination according to method mentioned by Drury and Wallington, (1980). The relative organs weight was calculated as following:

$$\text{Relative organs weight (ROW)\%} = \frac{\textbf{Organ weight (g)}}{\textbf{Total body weight (g)}} \times \mathbf{100}$$

Blood Sampling:

At the end of experiment period, 4 weeks, Blood samples were collected after 12 hours fasting at the end of the experiment using the abdominal aorta in which the rats were scarified under ether anesthetized. Blood samples were received in to clean dry centrifuge tubes and left to clot at room temperature for 28 minutes, then centrifuged for 10 minutes at 4000 rpm to separate the serum, which were carefully aspirated and transferred into clean cuvette tubes and stored frozen at-200c till analysis according to the method described by Schermer, (1967).

Biochemical investigations:

Lipids profile:

- **Determination of serum total cholesterol:**

Serum total cholesterol was determined according to the colorimetric method described by Thomas, (1992).

- **Determination of serum triglycerides:**

Serum triglycerides (T.G) was determined by enzymatic method using kits according to the Young, (1975) and Fossati, (1982).

- **Determination of high density lipoprotein cholesterol (HDL-c):**

HDL-c was determined according to the method described by Friedewaid (1972) and Grodon & Amer (1977).

Serum high density lipoprotein cholesterol (HDL-c) was measured using the modified kinetic method according to Allain, (1974) by using kit supplied by Human, Germany.

- **Determination of LDL and VLDL – Cholesterol:**

The determination for LDL (low density lipoproteins) and VLDL (very low density lipoproteins) carried out according to the method of Lee and Nieman, (1996).

- **Calculation of very low density lipoprotein cholesterol (VLDL-c):**

VLDL-c was calculated in mg/dl according to Lee and Nieman, (1996) using the following formula:

VLDL-c (mg/dl) =Triglycerides / 5

- **Calculation of low density lipoprotein cholesterol (LDL-c):**

Serum low density lipoprotein cholesterol (LDI-c) was calculated in mg/dl according to Lee and Nieman, (1996) as follows:

LDL Concentration (mg/dl) = Total Cholesterol – (HDL-c – VLDL-c)

Liver functions:

- **Determination of serum alanine amino transferase (ALT):**

ALT activities were measured in serum using the modified kinetic method of Tiez, (1976) by using kit supplied by Human, Germany.

- **Determination of serum aspartate amino transferase (AST):**

AST activities were measured in serum using the modified kinetic method of Henary, (1974) by using kit supplied by human, Germany.

- **Determination of serum alkaline phosphatase(ALP):**

Determination of serum ALP was carried out according to the method of Moss, (1982)

Kidney functions:

- **Determination of serum urea:**

Urea was determination in serum using the modified kinetic method or liquicolor of Patton and Crouch, (1977) by using kit supplied by Human, Germany.

- **Determination of serum uric acid:**

Serum uric acid was determined calorimetrically according to the method of Barham and Tinder, (1972).

- **Determination of serum creatinine:**

Serum creatinine was determined according to the method described by Henary, (1974).

- **Determination of blood glucose:**

Serum glucose was measured using the modified kinetic method according to Kaplan, (1984) by using kit supplied by spin react. Spain.

Histopathological investigation:

Small specimens of the organ liver and kidney were taken from each experimental groups, fixed in neutral buffered formalin, dehydrated in ascending concentration of ethanol (70, 80, 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).

Results and Discussion:

Data presented in Table (1) the highest value recorded for positive control group, while negative control group recorded the lowest value with significant (P≤0.05) differences. The mean values were 2.86 ± 0.17 and 1.27 by ± 0.41 g/28 day, respectively.

For treated groups the highest body weight gain value was recorded for 2.5% lemongrass leaves powder, while 2% lemongrass aqueous leaves extract group recorded the lowest value with significant (P≤0.05) differences. The mean values were 2.55 a ± 0.31 and 0.84 c ± 0.05 g/28 day, respectively. There were no significant differences between negative control and 5% lemongrass leaves powder groups. Also, There were no significant differences between positive control and 2.5% lemongrass leaves powder groups.

Shimaa, (2019) reported that the protective groups rats fed on LEMS (lemongrass) levels at (10, 20 & 30%) diets showed significant higher in feed intake (FI), body weight gain (BWG), body weight %.

Modak and Mukhopadhaya, (2011) reported that citral-treated rats show a dose-dependent reduction in body weight gain.

Table 1: Effect of lemongrass aqueous leaves extract and powder on body weight gain of diabetic rats :-

Groups	Body weight gain (g/28 day)
G_1 Control (-)	$1.27^{bc} \pm 0.41$
G_2 Control (+)	$2.86^{a} \pm 0.17$
G_3 (2.5% lemongrass leaves powder)	$2.55^{a} \pm 0.31$
G_4 (5% lemongrass leaves powder)	$1.09^{bc} \pm 0.12$
G_5 (1% lemongrass aqueous leaves extract)	$1.57^{b} \pm 0.20$
G_6 (2% lemongrass aqueous leaves extract)	$0.84^{c} \pm 0.05$
LSD	0.43

Each value represents mean ± standard deviation. Mean under the same column bearing different superscript letters are different significantly ($p \leq 0.05$).

Hasim et al., (2015) indicated that the significant increase in the rate of live body weight and the total weight increase in the treatments of lemongrass leaves compared with the (control) treatment was due to the role of the active substances present in the lemon

leaves, such as Flavonoids, Linalool and Phenoles as stimulants of the digestive system and improving digestion.

These results in agreement with Ewenighi et al., (2013) who showed that, four weeks of treatment with the C. citratus extract elicits significant reductions in body weight.

Data presented in Table (2) and illustrated in Figs. (4,5) show the effect of lemongrass aqueous leaves extract and powder on liver and heart weight of diabetic rats. In case of liver weight, the highest value recorded for positive control group, while negative control group recorded the lowest value with significant (P≤0.05) differences. The mean values were 0.043 a ± 0.002 and 0.036 c ± 0.001 g, respectively.

For treated groups the highest liver weight value recorded for 2.5% lemongrass leaves powder, while 2% lemongrass leaves aqueous extract group recorded the lowest value with significant (P≤0.05) differences. The mean values were 0.039 b ± 0.002 and 0.026 e ± 0.002 g, respectively. There were no significant differences between and 5% lemongrass leaves powder and 2% lemongrass leaves aqueous groups.

According to a study performed by Genser et al., (2008) who observed that the liver weights were decreased by C. citratus extract treatment in diabetic dyslipidemic rats, perhaps because the extract inhibited either cholesterol deposition in the liver tissues or hepatic HMG CoA reductase activity.

For heart weight, the highest value recorded for positive control group, while negative control group recorded the lowest value with significant (P≤0.05) differences. The mean values were 0.007 a ± 0.002 and 0.002 c ± 0.001 g, respectively. There were no significant differences between all treated groups.

Table (2): Effect of lemongrass aqueous leaves extract and powder on liver and heart weight of diabetic rats:-

Groups	Liver weight (g)	Heart weight (g)
G_1 Control (-)	0.036 ^{c} ± 0.001	0.002 ^{b} ± 0.001
G_2 Control (+)	0.043 ^{a} ± 0.002	0.007 ^{a} ± 0.002
G_3 (2.5% lemongrass leaves powder)	0.039 ^{b} ± 0.002	0.005 ^{ab} ± 0.002
G_4 (5% lemongrass leaves powder)	0.028 ^{e} ± 0.001	0.003 ^{ab} ± 0.001
G_5 (1% lemongrass aqueous leaves extract	0.033 ^{d} ± 0.001	0.005 ^{ab} ± 0.001
G6 (2% lemongrass aqueous leaves extrac	0.026 e ± 0.002	0.004 ab ± 0.001
LSD	0.003	0.002

Each value represents mean ± standard deviation. Mean under the same column bearing different superscript letters are different significantly (p ≤ 0.05).

Data presented in Table (3) and illustrated in Figs. (9) show the effect of lemongrass aqueous leaves extract and powder on glucose levels of diabetic rats. The obtained results indicated that the highest value recorded for positive control group, while negative control group recorded the lowest value with significant (P≤0.05) differences. The mean values were 187.00 a ± 1.40 and 85.90 f ± 0.75 mg/dl, respectively.

For treated groups the highest glucose levels value recorded for 2.5% lemongrass leaves powder, while 2% lemongrass aqueous leaves extract group recorded the lowest value with significant (P≤0.05) differences. The mean values were 126.00 b ± 0.35 and 88.10 e ± 0.21 mg/dl, respectively.

These results are in agreement with Ademuyiwa et al., (2015) who stated that administration of lemongrass extract for 30 days caused a steady decrease in blood glucose levels Diabetics rats.

According to Boa duo et al., (2014); Lunyera et al., (2016); Garba et al., (2020) they reported that Cymbopogon citratus plants has hypoglycemic property in customary and hyperglycaemic mice.

Zhou et al., (2016) reported that Hypoglycemic activity of lemongrass is due to interaction of various bioactive chemical compounds (secondary metabolites) or several compounds in isolation.

These results in agreement with Ademuyiwa et al., (2015) who studied that administration of both ethanolic and aqueous extracts of Cymbopogon citratus at a dose of 200 mg/kg body weight for a period of 30 days to the test animals caused a steady decrease in their blood glucose level. The significant ($p<0.05$) decrease in the blood glucose of the test animals as compared to the control is a reflection of the hypoglycemic effect of the plant.

Ewenighi et al., (2013) reported and indicated that a significant reduction in glucose levels of alloxan-induced diabetic rats treated with lemongrass extract after weeks of treatment. It is thought that this reduction in glucose level may be due to the effect of essential oil, a substance similar to insulin, which confers hypoglycemic ability on the lemongrass. and these results supports the works of Mansour et al., (2002), Sheweita et al (2002); Adeneye and Agbaje, (2007) and Atiku et al., (2009), which demonstrated that lemongrass restored glucose levels to normal in four weeks of treatment in rats.

Abbas et al., (2018) showed that administration of extract of root and flower of lemongrass (Cymbopogon citratus) reduced the fasting and postprandial blood sugar levels.

Table 3: Effect of lemongrass aqueous leaves extract and powder on glucose levels of diabetic rats:-

Groups	Glucose (mg/dl)
G_1 Control (-)	85.90 ^{f} ± 0.75
G_2 Control (+)	187.00 ^{a} ± 1.40
G_3 (2.5% lemongrass leaves powder)	126.60 ^{b} ± 0.35
G_4 (5% lemongrass leaves powder)	99.30 ^{d} ± 0.82
G_5 (1% lemongrass aqueous leaves extract)	109.70 ^{c} ± 0.63
G_6 (2% lemongrass aqueous leaves extract)	88.10 ^{e} ± 0.21
LSD	1.41

Each value represents mean ± standard deviation. Mean under the same column bearing different superscript letters are different significantly ($p \leq 0.05$).

Data presented in Table (4) and illustrated in Figs. (10,11) show the effect of lemongrass aqueous leaves extract and powder on serum total cholesterol levels (TC) and serum triglycerides (TG) of diabetic rats. The obtained results indicated that the highest value of serum cholesterol levels recorded for positive control group, while negative control group recorded the lowest value with significant (P≤0.05) differences. The mean values were 129.60 a ± 0.31 and 73.20 f ± 0.31 mg/dl, respectively.

For treated groups the highest value of serum cholesterol levels recorded for 2.5% lemongrass leaves powder, while 2% lemongrass aqueous leaves extract group recorded the lowest value with significant (P≤0.05) differences. The mean values were 107.20 b ± 0.80 and 78.40 e ± 0.42 mg/dl, respectively.

In case of serum triglycerides, it could be concluded that the highest value of serum triglycerides levels recorded for positive control group, while negative control group recorded the lowest value with significant (P≤0.05) differences. The mean values were 157.80 a ± 0.55 and 66.20 f ± 0.49 mg/dl, respectively.

For treated groups the highest value of serum triglycerides levels recorded for 2.5% lemongrass leaves powder, while 2% lemongrass aqueous leaves extract group recorded the lowest value with significant (P≤0.05) differences. The mean values were 130.20 b ± 0.21 and 83.60 e ± 0.90 mg/dl, respectively.

Ewenighi et al ., (2013) showed that treatment with C. citratus extract over the course of several weeks significantly reduced body weight, blood glucose, TG, T-chol, and LDL levels in diabetic rats. The treated animals also exhibited significantly higher HDL levels than untreated control animals.

In a study performed by Agbafor and Akubugw , (2007) showed the anti-hypercholesterolemic potential of the ethanolic extracts of fresh C. citratus leaves. The cholesterol-lowering potential of the extract may also be ascribed to the modification of the intestinal cholesterol uptake, increased conversion of cholesterol to bile acids, and increased excretion of the formed bile acids, elicited by the extracts of C. citratus.

Table 4: Effect of lemongrass aqueous leaves extract and powder on serum total cholesterol levels (TC) and serum triglycerides (TG) of diabetic rats:-

Groups	Total cholesterol mg/dI	Triglycerides mg/dl
G_1 Control (-)	73.20 ^{f} ± 0.31	66.20 f ± 0.49
G_2 Control (+)	129.60 ^{a} ± 0.98	157.80 a ± 0.55
G_3 (2.5% lemongrass leaves powder)	107.20 ^{b} ± 0.80	130.20 b ± 0.21
G_4 (5% lemongrass leaves powder)	84.30 ^{d} ± 0.23	95.60 d ± 0.71
G_5 (1% lemongrass aqueous leaves extract)	89.80 ^{c} ± 0.17	96.80 c ± 0.68
G_6 (2% lemongrass aqueous leaves extract)	78.40 ^{e} ± 0.42	83.60 e ± 0.90
LSD	1.02	1.12

Each value represents mean ± standard deviation. Mean under the same column bearing different superscript letters are different significantly ($p \leq 0.05$).

Data presented in Table (5) and illustrated in Figs. (12-14) show the effect of lemongrass aqueous leaves extract and powder on serum lipid profile levels: high density lipoprotein cholesterol (HDL-c), low density lipoprotein cholesterol (LDL–c) and very low density lipoprotein cholesterol (VLDL–c) of diabetic rats. It's clear to notice that the highest high density lipoprotein cholesterol levels recorded for negative control group, while positive control group recorded the lowest value with significant differences. The mean values were 39.10 a ± 0.25 mg/dl and 24.60 e ± 0.38 mg/dl, respectively.

On the other hand, the value of high density lipoprotein cholesterol levels of treated groups recorded for 2% lemongrass aqueous leaves extract group, while 2.5% lemongrass leaves powder group recorded the lowest value with significant differences. The mean values were 37.16 b ± 0.11 mg/dl and 29.30 d ± 0.43 mg/dl, respectively. There were no significant differences between 2.5% lemongrass leaves powder and 1% lemongrass aqueous leaves extract groups.

The same table also data in indicated that the highest low density lipoprotein cholesterol levels recorded for positive control group, while negative control group recorded the

lowest value with significant differences. The mean values were 73.44 a ± 0.49 mg/dl and 20.56 f ± 0.52 mg/dl, respectively.

For treated groups the highest value of low density lipoprotein cholesterol levels recorded for 2.5% lemongrass leaves powder, while 2% lemongrass aqueous leaves extract group recorded the lowest value with significant (P≤0.05) differences. The mean values were 51.86 b ± 0.33 and 24.52 e ± 0.13 mg/dl, respectively.

Hanaa, (2013) and Nuntiya et al., (2018) reported that LEMS (lemongrass) at a different at levels caused significant decreases in serum triglyceride, total cholesterol, LDL-cholesterol levels supposedly the presence of sterols in plants inhibits the body's absorption of cholesterol. Using a 30% concentration of LEMS indicates significant reduction in the total plasma protein level, lipid profile and glucose levels, without a reduction in high density lipoproteins (HDLc) in rats.

In case of very low density lipoprotein cholesterol the highest value recorded for positive control group, while negative control group recorded the lowest value with significant differences. The mean values were 31.56 a ± 0.11 mg/dl and 13.24 f ± 0.10 mg/dl, respectively.

For treated groups the highest value of very low density lipoprotein cholesterol levels recorded for 2.5% lemongrass leaves powder, while 2% lemongrass aqueous leaves extract group recorded the lowest value with significant (P≤0.05) differences. The mean values were 26.04 b ± 0.04 and 16.72 e ± 0.18 mg/dl, respectively.

Ravi et al., (2005) and Emeka and Funmilayo, (2011) indicated that the level of the LDL-Cholesterols in both ethanolic and aqueous extracts lowered when compared with the control group and the level of the HDL-Cholesterol in the treated groups. Thus, blood serum cholesterol level was found to be down regulated in this study. It is known that high blood cholesterol levels and hyper-lipidemia can be the consequence and frequently associated with diabetes.

It was reported that oral treatment of lemongrass alcoholic or aqueous extracts (200–1000 mg/kg bw) to non-diabetic, hyperlipidemic and diabetic animals exhibited antihyperlipidemic action Ademuyiwa et al., (2015) and Ekpenyong et al., (2014).

Table (5): Effect of lemongrass aqueous leaves extract and powder on serum lipid profile levels of diabetic rats:-

Groups	HDL-c mg/dl	LDL-c mg/dl	VLDL-c mg/dl

G_1 Control (-)	39.10 ^{a} ± 0.25	20.56 f ± 0.52	13.24 f ± 0.10
G_2 Control (+)	24.60 ^{e} ± 0.38	73.44 a ± 0.49	31.56 a ± 0.11
G_3 (2.5% lemongrass leaves powder)	29.30 ^{d} ± 0.43	51.86 b ± 0.33	26.04 b ± 0.04
G_4 (5% lemongrass leaves powder)	32.70 ^{c} ± 0.36	32.48 d ± 0.27	19.12 d ± 0.14
G_5 (1% lemongrass aqueous leaves extract)	30.01 ^{d} ± 0.75	40.43 c ± 0.72	19.36 c ± 0.14
G_6 (2% lemongrass aqueous leaves extract)	37.16 ^{b} ± 0.11	24.52 e ± 0.13	16.72 e ± 0.18
LSD	0.76	0.81	0.22

Each value represents mean ± standard deviation. Mean under the same column bearing different superscript letters are different significantly ($p \leq 0.05$). HDL-c = High density lipoprotein cholesterol. LDL-c = Low density lipoprotein cholesterol. VLDL -c = Very low density lipoprotein cholesterol.

Data presented in Table (6) and illustrated in Figs. (15-17) show the effect of lemongrass aqueous leaves extract and powder on liver functions levels (ALP, AST and ALT) of diabetic rats. The obtained results indicated that the highest value of serum ALP levels recorded for positive control group, while negative control group recorded the lowest value with significant (P≤0.05) differences. The mean values were 196.20 a ± 0.88 and 118.80 f ± 0.29 U/L, respectively.

For treated groups the highest value of serum ALP levels recorded for 2.5% lemongrass leaves powder, while 2% lemongrass aqueous leaves extract group recorded the lowest value with significant (P≤0.05) differences. The mean values were 172.80 b ± 0.54 and 131.60 e ± 0.36 U/L, respectively.

In case of serum AST, it could be concluded that the highest value of serum AST levels recorded for positive control group, while negative control group recorded the lowest value with significant (P≤0.05) differences. The mean values were 228.10 a ± 0.90 and 117.45 f ± 0.77 U/L, respectively.

For treated groups the highest value of serum AST levels recorded for 2.5% lemongrass leaves powder, while 2% lemongrass aqueous leaves extract group recorded the lowest value with significant (P≤0.05) differences. The mean values were 201.60 b ± 0.50 and 128.40 e ± 0.64 U/L, respectively.

The same table also data in indicated that the highest value of serum ALT levels recorded for positive control group, while negative control group recorded the lowest value with significant differences. The mean values were 112.00 a ± 0.60 and 33.40 f ± 0.10 U/L, respectively.

For treated groups the highest value of serum ALT levels recorded for 2.5% lemongrass leaves powder, while 2% lemongrass aqueous leaves extract group recorded the lowest

value with significant (P≤0.05) differences. The mean values were 61.90 b ± 0.42 and 39.20 e ± 0.13 U/L, respectively.

Garba et al., (2020) showed that the liver glycogen content, serum AST and ALP levels were significantly decreased whereas serum ALT, total proteins and albumin were elevated in the DBC group compared to the NC group.

From previous studies it were showed that the decrease in serum ALT and AST in all rats fed on LEMS may be caused rich contained in polyphenols Haggag , (2015). Furthermore, Nuntiya et al., (2018) indicated that, protective group with LEMS at level 30% drug group (α LA) resulted in significant decrease in serum ALT and AST. Thence, the reduction in serum levels of AST, ALT, and ALP by lemongrass leaves therapy is an indication of establishing of plasma membrane as well as repair in tissue of hepatic. This effect shows that return to normal with the healing of hepatocytes may be to their qualitative phytochemical analysis which shows the presence of flavonoids in LEMS.

Table (6): Effect of lemongrass aqueous leaves extract and powder on liver functions levels (ALP, AST and ALT) of diabetic rats:-

Groups	ALP (U/L)	AST (U/L)	ALT (U/L)
G1 C (-)	118.80 f ± 0.29	117.45 f ± 0.77	33.40 f ± 0.10
G2 C (+)	196.20 a ± 0.88	228.10 a ± 0.90	112.00 a ± 0.60
G3 (2.5% lemongrass leaves powder)	172.80 b ± 0.54	201.60 b ± 0.50	61.90 b ± 0.42
G4 (5% lemongrass leaves powder)	148.40 d ± 0.32	153.10 d ± 0.29	42.10 d ± 0.19
G5 (1% lemongrass aqueous leaves extract)	160.80 c ± 0.70	185.20 c ± 0.47	50.80 c ± 0.05
G6 (2% lemongrass aqueous leaves extract)	131.60 e ± 0.36	128.40 e ± 0.64	39.20 e ± 0.13
LSD	0.99	1.12	0.61

Each value represents mean ± standard deviation. Mean under the same column bearing different superscript letters are different significantly ($p \leq 0.05$).

Eraj et al., (2016) reported that aqueous extract of C. citratus was administered at a dose of 200 mg/kg body weight orally for 15 days to healthy rabbit. The extract exhibited significant reduction in biochemical parameters (ALP, SGOT, SGPT, GT and TB) as observed in their study.

Light microscopic examination of liver of rats from group 1 revealed the normal histological architecture of hepatic lobule from central vein and hepatocytes (Figs. 1 & 2). On the other hand, examined sections from group 2 exhibited marked vacuolar

degeneration of hepatocytes (Figs. 3, 4 & 5) and focal hepatocellular necrosis associated with inflammatory cells infiltration (Fig. 4) as well as oval cells proliferation (Fig. 5). Meanwhile, liver of rats from group 3 showed slight congestion of central vein and slight activation of Kupffer cells (Figs. 6 & 7). Moreover, liver sections from rats in group 4 revealed Kupffer cells activation (Figs. 8 & 9) and small focal hepatocellular necrosis associated with inflammatory cells infiltration (Fig. 9). However, liver of rats from group 5 revealed mild changes described as sinusoidal leukocytosis (Fig. 10) and congestion of central vein (Fig. 12). Moreover, regression of lesions was noticed in liver from group 6, examined sections showed Kupffer cells activation and congestion of central vein (Fig. 12).

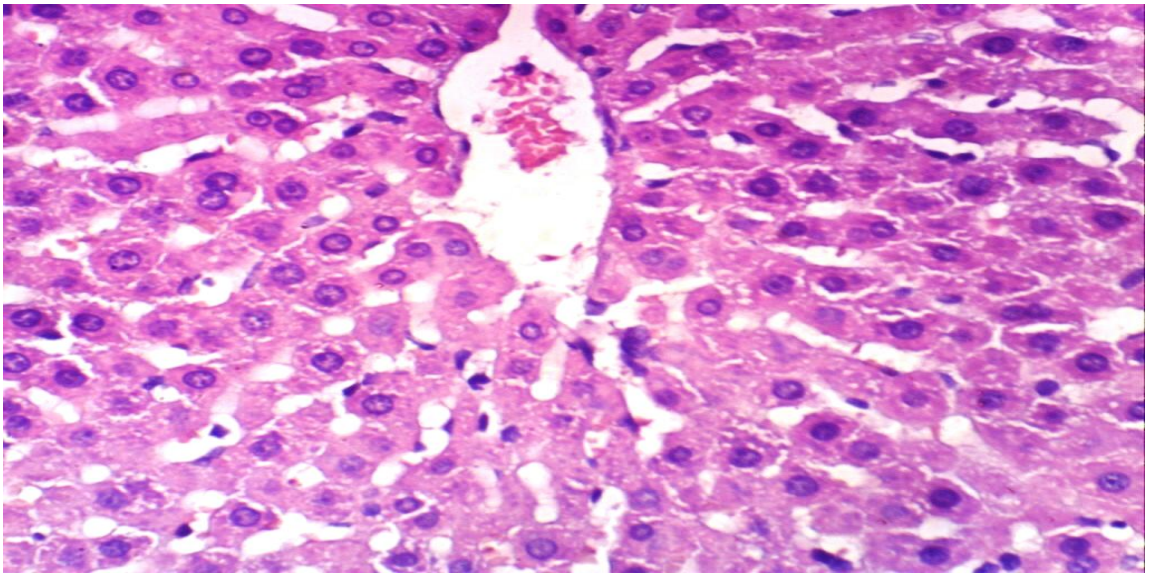

Fig. (1): Liver of rat from group 1 showing the normal histological architecture of hepatic lobule (H & E X 400).

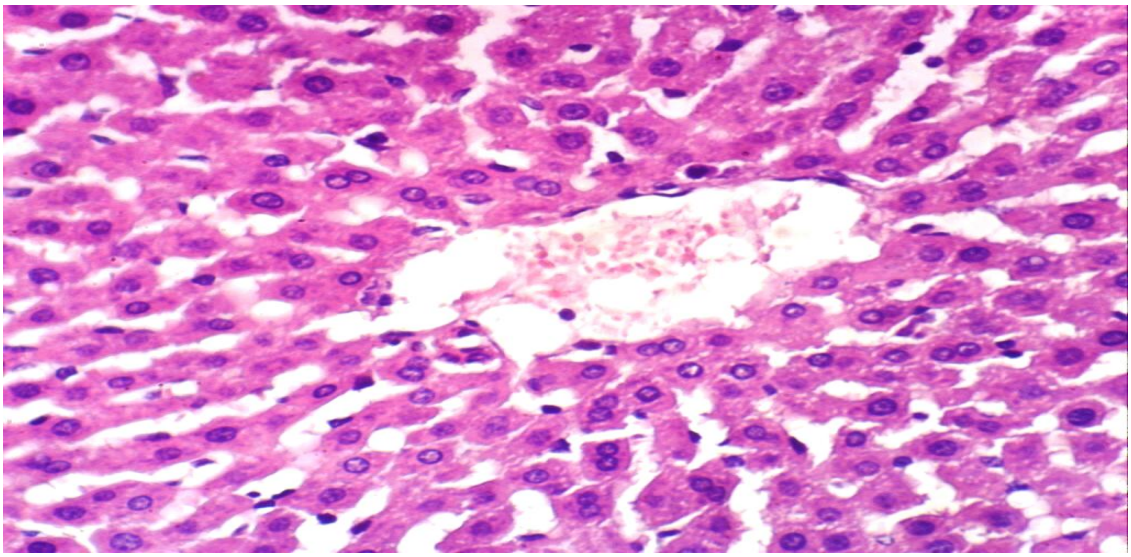

Fig. (2): Liver of rat from group 1 showing the normal histological architecture of hepatic lobule (H & E X 400).

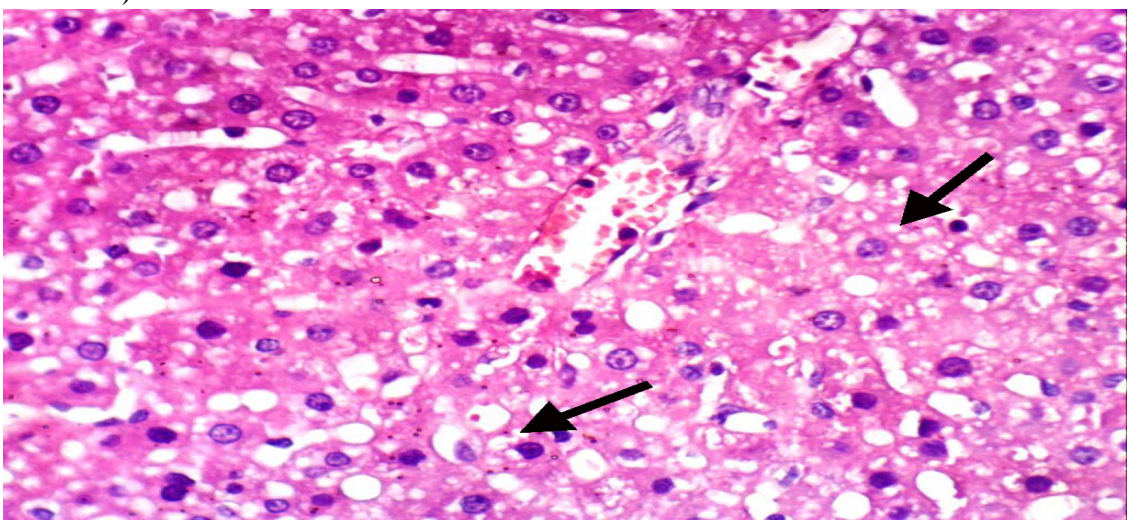

Fig. (3): Liver of rat from group 2 showing marked vacuolar degeneration of hepatocytes (arrow) (H & E X 400).

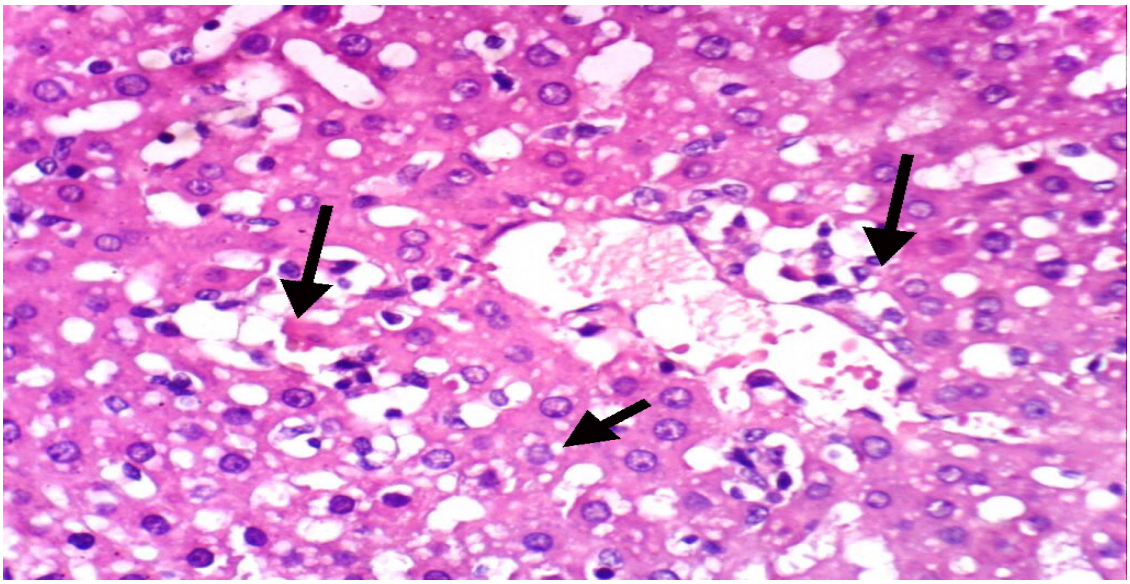

Fig. (4): Liver of rat from group 2 showing marked vacuolar degeneration of hepatocytes (short arrow) and focal hepatocellular necrosis associated with inflammatory cells infiltration (long arrows) (H & E X 400).

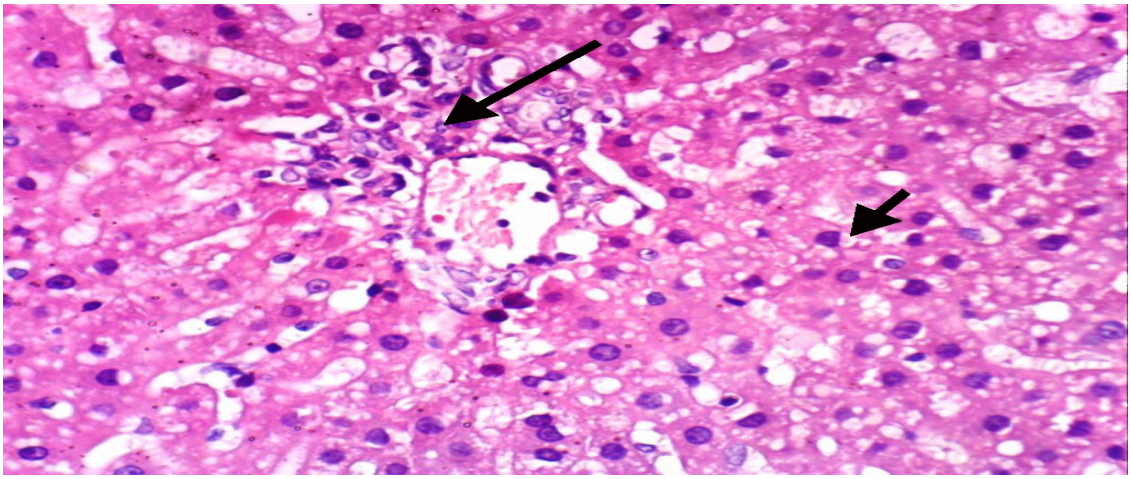

Fig. (5): Liver of rat from group 2 showing marked vacuolar degeneration of hepatocytes (short arrow) and oval cells proliferation (long arrows) (H & E X 400).

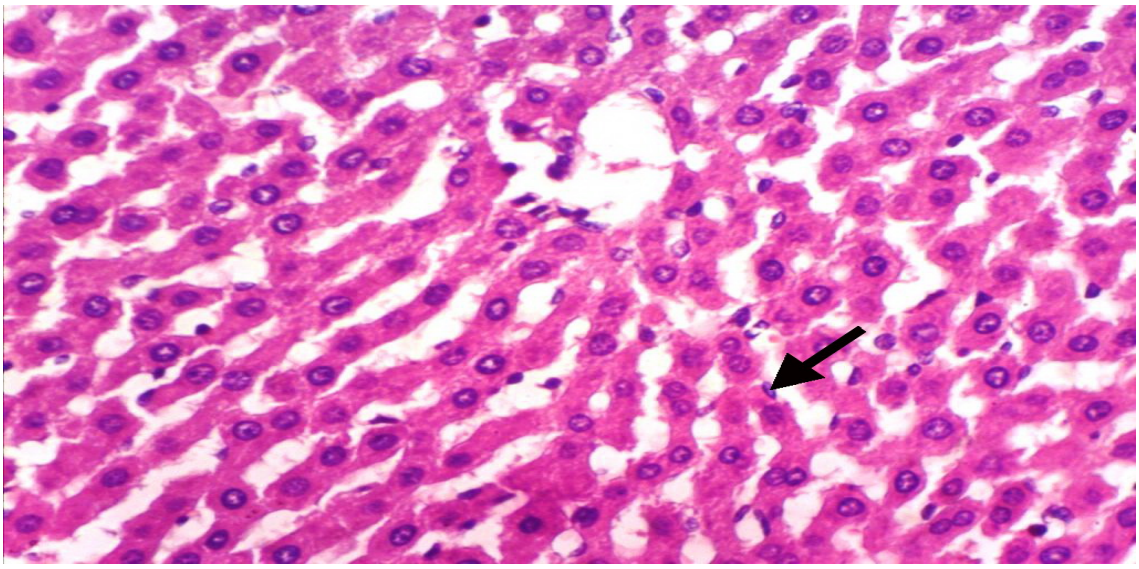

Fig. (6): Liver of rat from group 3 slight activation of Kupffer cells (arrow) (H & E X 400).

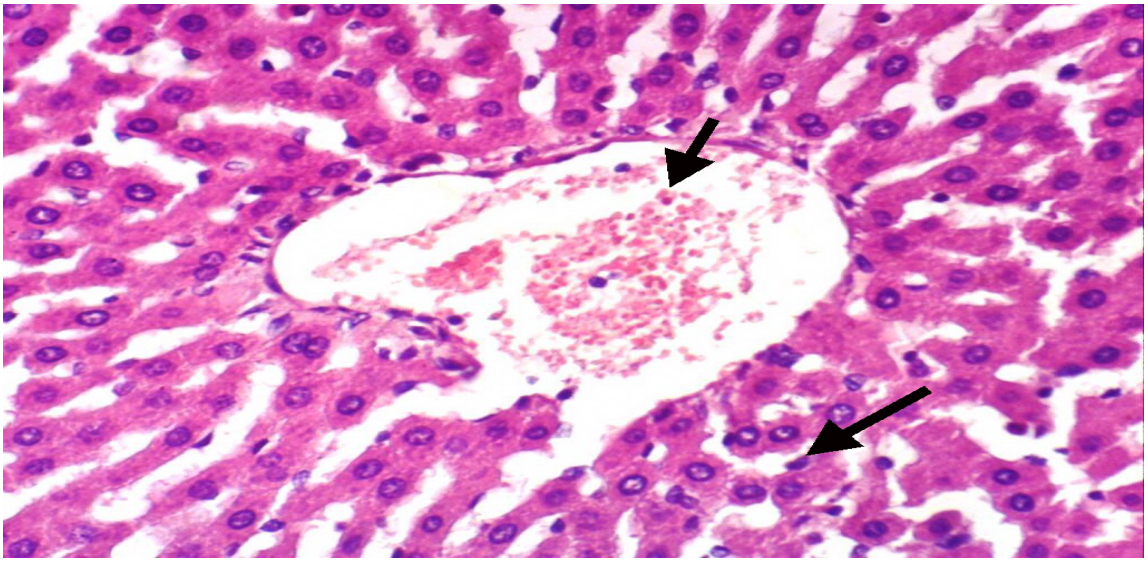

Fig. (7): Liver of rat from group 3 slight congestion of central vein (short arrow) and slight activation of Kupffer cells (long arrow) (H & E X 400).

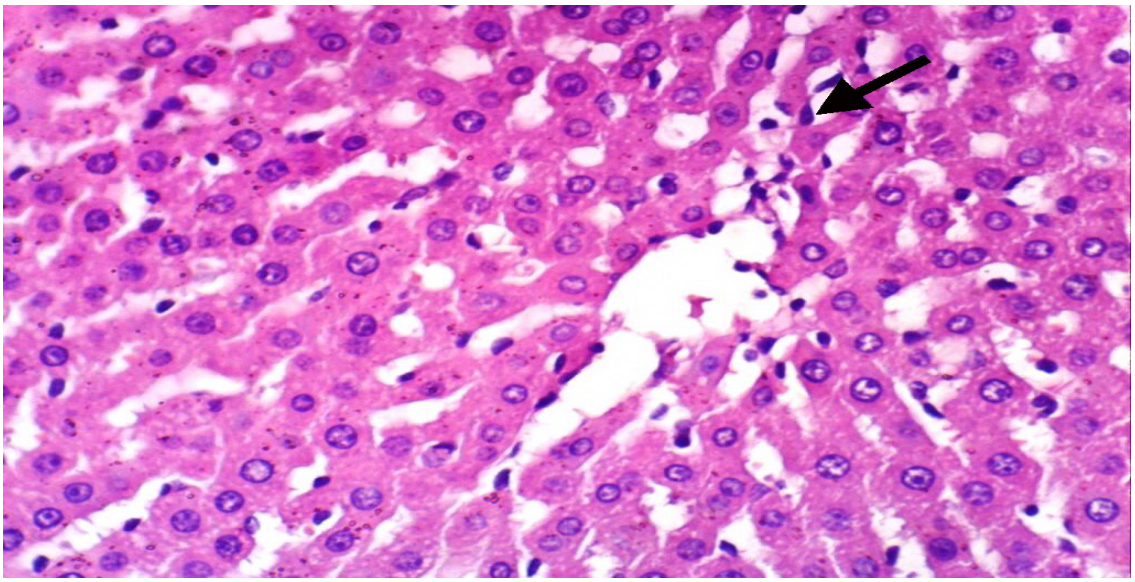

Fig. (8): Liver of rat from group 4 activation of Kupffer cells (arrow) (H & E X 400).

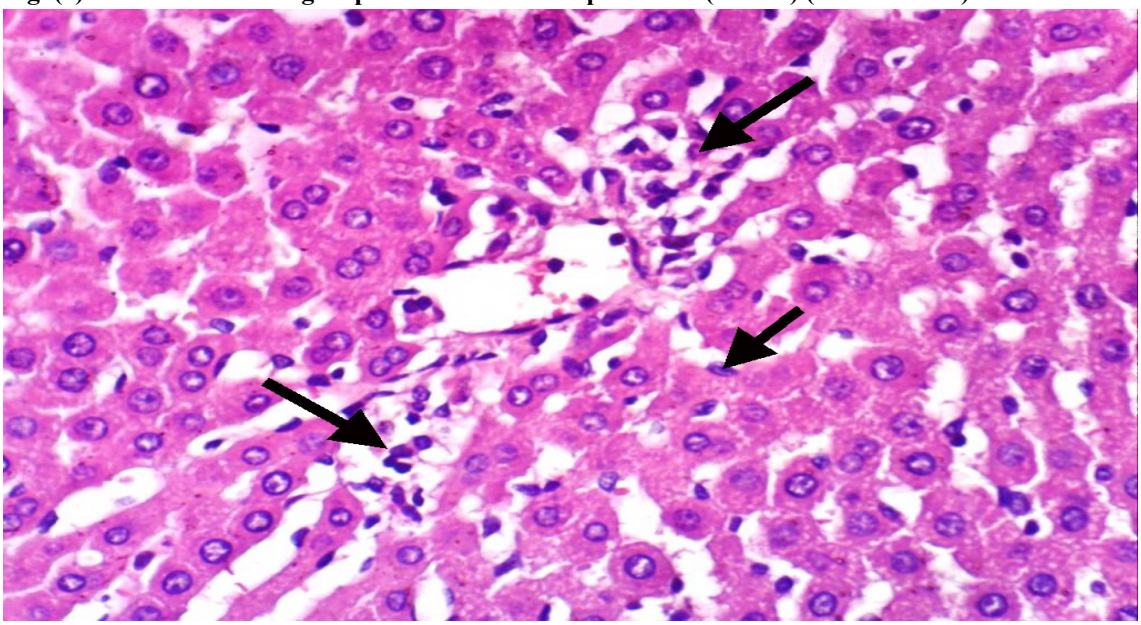

Fig. (9): Liver of rat from group 4 showing Kupffer cells activation (short arrow) and small focal hepatocellular necrosis associated with inflammatory cells infiltration (long arrows) (H & E X 400).

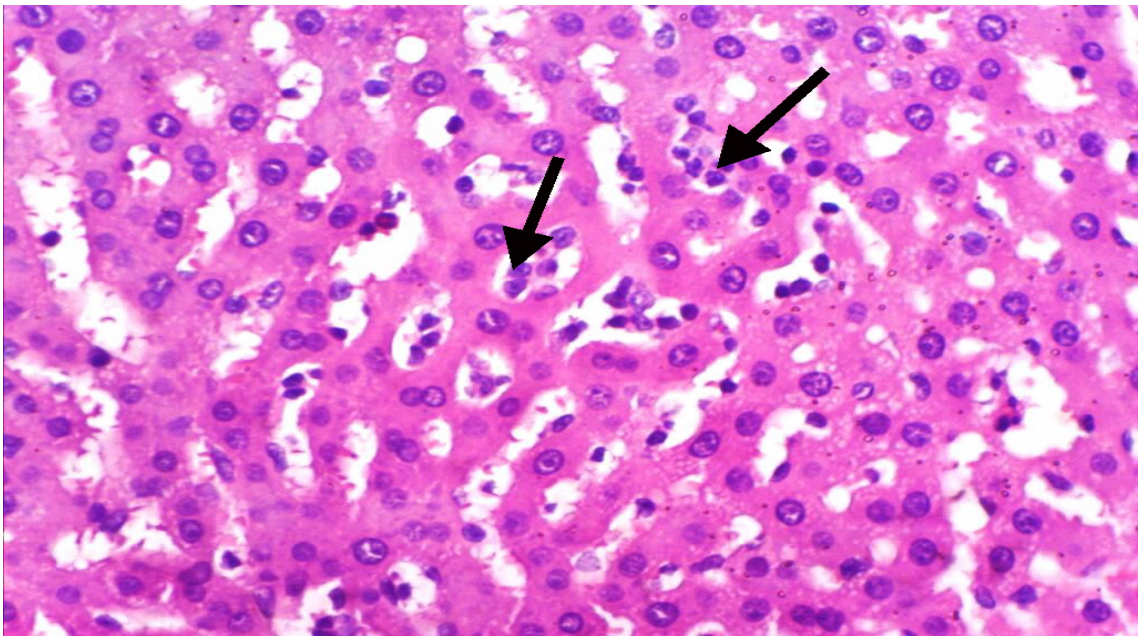

Fig. (10): Liver of rat from group 5 showing sinusoidal leukocytosis (arrows) (H & E X 400).

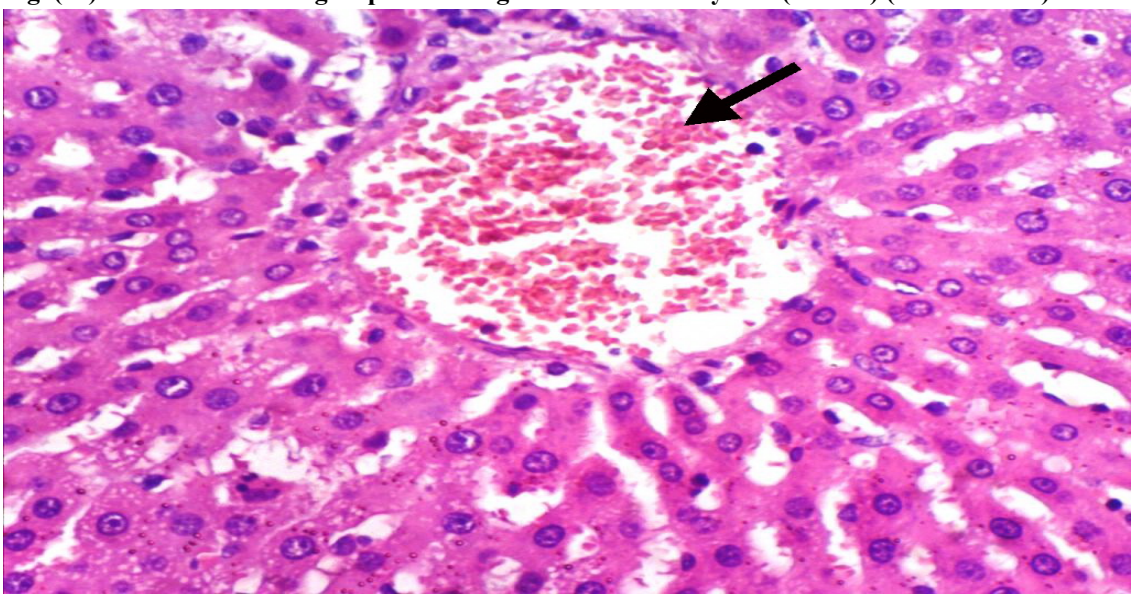

Fig. (11): Liver of rat from group 5 showing congestion of central vein (arrow) (H & E X 400).

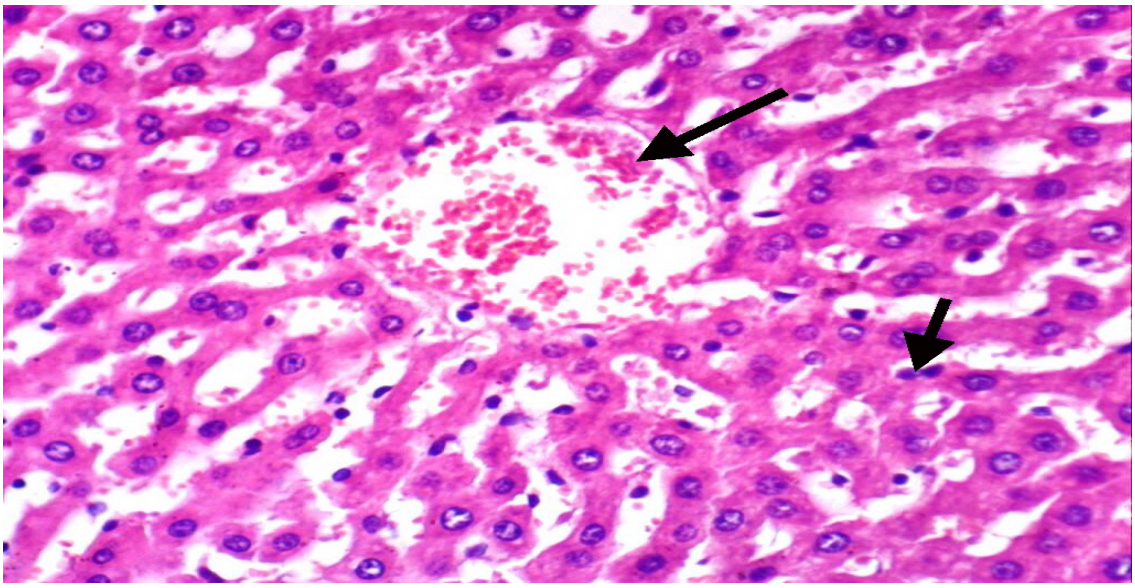

Fig. (12): Liver of rat from group 6 showing Kupffer cells activation (short arrow) and congestion of central vein (long arrow) (H & E X 400).

Conclusion:

In conclusion, lemongrass aqueous leaves extract and powder had an ameliorative effect on hyperglycemia, and diabetes mellites index. demonstrated antidiabetic actions via improving body weight gain, reducing food and fluid intake and hyperglycemia, improving glucose tolerance ability, and may be potential therapeutic agent for atherogenic cardiovascular diseases.

Conflict of interest

The authors declare that they have no conflict of interest concerning the publication of this article. This article is extracted from a Master's thesis submitted to the Department of Nutrition and Food Science, Faculty of Home Economics, Menoufia University, Shebin El-Kom, Egypt.

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التأثيرالمضاد للسكري للمستخلص المائي لأوراق عشبة الليمون ومسحوق أوراقها علي الفئران البيضاء المصابه بالسكري

محمد مصطفي السيد ، مي محمود خفاجي ، أمينه محمد راتب
قسم التغذية وعلوم الأطعمة، كلية الاقتصاد المنزلي، جامعة المنوفية، شبين الكوم، مصر

الملخص العربي

تم إجراء الدراسه الحاليه لمعرفة التأثيرات المحتمله لاستخدام تركيزات مختلفه من المستخلص المائي لأوراق عشبة الليمون ومسحوقها علي الفئران المصابه بمرض السكر بتأثير الألوكسان وعلي الخلل الفسيولوجي الحادث في الكبد والكلي. تم استخدام 30 فأر أبيض وتم تقسيمهم إلي 6 مجموعات. كل مجموعه تحتوي علي 5 فئران إحداهما كمجموعه ضابطه سالبه تتغذي علي الوجبه القياسيه.أما المجموعات الأخري فتم إحداث إصابه بالسكر عن طريق الحقن بواسطة الألوكسان بتركيز 150 مجم / كجم من وزن الجسم. وتتغذي أيضا المجموعه الضابطه الموجبه علي الوجبه القياسية. بينما المجموعات الأخري أضيف لها أوراق عشبة الليمون المستخدمه بتركيزات 2.5 ، 5% لكل منهما من الوجبه الأساسيه علي هيئة مطحون و بتركيزات 1 ، 2% في صورة مستخلص مائي. وتم قياس مستوي السكر في الدم ووظائف الكبد (إنزيم ناقلة أمين الألانين ، إنزيم ناقلة أمين الأسبارتات، إنزيم الفوسفاتاز القلوي) ووظائف الكلي (اليوريا ، حمض اليوريك و الكرياتين) والكوليسترول الكلي والجليسريدات الثلاثيه والليبوبروتينات(الليبوبروتين منخفض الكثافه ، الليبوبروتين مرتفع الكثافه ، والليبوبروتين منخفض الكثافه جدا) كذلك إجراء الفحص الهستوباثولوجي للكبد والكلي. وقد أظهرت نتائج هذه الدراسه أن تناول أوراق عشبة الليمون سواء في صورة مسحوق أو مستخلص مائي نتج عنه تحسن في مستوي السكر في الدم ووظائف الكلي والكبد ودهون الدم.

الكلمات الكاشفه مستوي جلوكوز الدم ، دهون الدم ، التحاليل الكيميائية ، وظائف الكبد