EFFECT OF CASSIA AURICULATA FLOWERS ON CHANGES IN THE FATTY ACID COMPOSITION IN DIABETIC RATS

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Article History: Received: 19.04.2023 **Revised:** 14.05.2023 **Accepted:** 03.07.2023

Abstract

Cassia auriculata L (CFEt). (Ceasalpiniaceae) has been used traditionally as antidiabetic and has been proven scientifically to possess high antioxidant activity and anticancer properties. In experimental diabetes, enzymes of glucose and fatty acid metabolism are markedly altered. Persistent hyperglycaemia is a major contributor to such metabolic alterations, which lead to the pathogenesis of diabetic complications. Fatty acids influence translocation of glucose transporters and insulin receptor binding and signalling, in addition to cell membrane fluidity and permeability. It is thus suggested that fatty acids may have an essential role in the development of insulin receptor and diabetes. Specific combinations of fatty acids within phospholipids and triglycerides were indicated to exhibit the strongest associations with the risk of diabetes. The aim of this study was to evaluate the effect of CFEt on blood glucose, plasma insulin and fatty acid composition of total lipids in liver, kidney and brain of control and streptozotocin diabetic rats. The analysis of fatty acids showed that there was a significant increase in the concentrations of palmitic acid (16:1), stearic acid (18:0) and oleic acid (18:1) acid in liver, kidney and brain, whereas the concentrations of linolenic acid (18:3) and arachidonic acid (20:4) were significantly decreased. Oral administration of CFEt at 0.45 mg/kg body weight to diabetic rats decreased the concentrations of fatty acids, viz., palmitic, stearic, and oleic acid whereas linolenic and arachidonic acid were elevated. These biochemical observations were supplemented by histopathological examination of liver and kidney section.These results suggest that CFEt exhibits antidiabetic and antihyperlipidemic effects in STZ induced diabetic rats. It also prevents the fatty acid changes produced during diabetes.

Keywords: Diabetes, *Cassia Auriculata*, Glibenclamide Blood Glucose, Insulin, Fatty Acids.

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DOI: 10.31838/ecb/2023.12.s3.587

1. INTRODUCTION

Diabetes mellitus, disorder of carbohydrate metabolism characterized by impaired ability of the body to produce or respond to insulin and thereby maintain proper levels of sugar (glucose) in the blood. Diabetes is a major cause of morbidity and mortality, though these outcomes are not due to the immediate effects of the disorder [1]. They are instead related to the diseases that develop as a result of chronic diabetes mellitus. These include diseases of large blood vessels (macrovascular disease, including coronary heart disease and peripheral arterial disease) and small blood vessels (microvascular disease, including retinal and renal vascular disease), as well as diseases of the nerves [2].

Diabetes is due to either the pancreas not producing enough insulin, or the cells of the body not responding properly to the insulin produced. Diabetes, if left untreated, leads to many health complications. Untreated or poorly treated diabetes accounts for approximately 1.5 million deaths per year. As of 2019, an estimated 463 million people had diabetes worldwide accounting for 8.8% of the adult population. Type 2 diabetes makes up about 90% of all diabetes cases. The prevalence of the disease continues to increase, most dramatically in low- and middle-income nations. Rates are similar in women and men, with diabetes being the 7th-leading cause of death globally [3].

Fatty acid content of the cell membrane regulates several physiological systems, including membrane fluidity, cellular activities, ion permeability, insulin receptor affinity, translocation of glucose transporters interacting with second messengers, and membrane fluidity. All of these alterations can alter the tissue and organ insulin sensitivity [4]. Fatty acids in the ester form are generally present as triglycerides, phospholipids and cholesterol esters. As esters of phospholipids they form an important part of the cell membrane, while as triglyceride they constitute an important source of stored energy [4].

During the process of injury, repair and cell growth, the fatty acids in phospholipids undergo severe modification. Earlier report showed that there is an alteration in the fatty acid composition in plasma and erythrocyte membrane of diabetic patients. Pari and Murugan, [2] reported that there is a significant alteration in the fatty acid composition of serum and variety of tissues in experimental diabetes /2/. Previous studies have also reported that the extent of hepatic regeneration was higher in phospholipid fraction of long chain triglyceride groups [5]. The fatty acid composition of cell membranes can influence membrane-associated phenomena such as the interaction between insulin and its receptor [6].

Diabetes mellitus is becoming pandemic and despite the recent upsurge in new drugs to treat and prevent the condition, its prevalence continues to soar. Despite the great strides that have been made in the understanding and management of diabetes, the disease and disease related complications are increasing unabated. Parallel to this, recent developments in understanding the pathophysiology of the disease process have opened up several new avenues to identify and develop novel therapies to combat the diabetic plaque [7].

Therefore, as the disease is progressing unabated, there is a need of identifying indigenous natural resources in order to procure them and study in detail their potential on different newly identified targets in order to develop them as new therapeutics [8]. Currently available drug regimes for management of diabetes mellitus have certain drawbacks and therefore, there is a need for safer and more effective antidiabetic drugs. The belief that natural medicines are much safer than synthetic drugs has gained popularity in recent years and lead to tremendous growth of phytopharmaceutical usage [9].

Antihyperglycemic effects of these plants is due to their ability to restore the function of pancreatic tissues by causing an increase in insulin output or inhibit the intestinal absorption of glucose or to the facilitation of metabolites in insulin dependent processes. Hence treatment with herbal drugs has an effect on protecting β-cells and smoothing out fluctuation in glucose levels [10]. In general, there is very little biological knowledge on the specific modes of action in the treatment of diabetes, but most of the plants have been found to contain substances like glycosides, alkaloids, terpenoids, flavonoids etc. that are frequently implicated as having antidiabetic effects [11].

For various reasons in recent years the popularity of complementary medicine has increased. Dietary measures and traditional plant therapies as prescribed by ayurvedic and other indigenous system of medicine were used commonly in India [11]. Beneficial actions of diets on the amelioration of diabetic symptoms are well documented.

Cassia auriculata L. (Ceasalpiniaceae) is a shrub that has attractive yellow flowers, commonly used for the treatment of skin disorders and body odour. It is a native plant present in different parts of India. Indigenous people use various parts of the plant for diabetes mellitus. It is widely used in

Ayurvedic medicine as a "Kalpa drug" which contains five parts of the shrub (roots, leaves, flowers, bark and unripe fruits) which are taken in equal quantity, dried and then powdered to give "Avarai Panchaga Choornam", for the control of sugar levels and reduction of symptoms such as polyuria and thirst in diabetes [12]. A literature survey showed that a decoction of leaves, flowers, and seeds of the *Cassia auriculata* mediate an antidiabetic effect [13]. Thus, the available reports show that very little work has been done with respect to *Cassia auriculata* flowers, other than its hypoglycemic effects. In our previous study, we have demonstrated the antidiabetic effect of *Cassia auriculata* flower extract (CFEt) in streptozotocin (STZ) induced diabetic rats [14].

To our knowledge, no other biochemical investigations had been carried out on the effect of CFEt in control and STZ induced diabetic rats. So, the present investigation was carried out to study the effect of CFEt on fatty acid composition and lipids in control and diabetic rats.

2. MATERIALS AND METHODS

Animals
Studies were performed on adult male albino rats of Wistar strain weighing 180-220g. According to the experimental protocol approved by the Committee for Research and Animal Ethics of Annamalai University, animals were housed in cages and maintained in 24 ± 2; º C normal temperature and a 12 hour light/dark cycle. The animals were fed on pellet diet (Lipton India Ltd., Mumbai) and water *ad libitum*.

Chemicals
STZ was obtained from Himedia Laboratory Limited, Mumbai, India. All other reagents used were of analytical grade.

Plant Material
Tanner's cassia flowers were collected freshly from Neyveli, Cuddalore District, Tamil Nadu, India. The plant was identified and authenticated at the Herbarium of Botany Directorate in Annamalai University. A voucher specimen (No.231) was deposited in the Botany Department of Annamalai University.

Preparation of plant extract
500 g of Tanner's cassia flowers were extracted with 1,500 ml of water by the method of continuous hot extraction at 60ºC for six hours and evaporated. The residual extract was dissolved in water and used in the study [15].

Induction of experimental diabetes
A freshly prepared solution of STZ (45 mg/kg i.p) in 0.1 M citrate buffer, pH 4.5 was injected intraperitoneally in a volume of 1 ml/kg. After 48 hours of STZ administration, rats with moderate diabetes having glycosuira and hyperglycaemia (i.e. with a blood glucose of 200- 300 mg/dl) were taken for the experiment [15].

Experimental procedure
In the experiment, a total of 36 rats (30 diabetic surviving rats, six normal rats) were used. The rats were divided in to six groups of six rats each.

Group 1: Normal untreated rats.
Group 2: Diabetic control rats given 1 ml of aqueous solution daily using an intragastric tube for 45 days.
Group 3: Diabetic rats given CFEt (0.45 g/kg body weight) in 1 ml of aqueous solution daily using an intragastric tube for 45 days.
Group 4: Diabetic rats given glibenclamide (600 μg/ kg body weight) in 1 ml of aqueous solution daily using an intragastric tube for 45days.

At the end of 45 days, the animals were deprived of food overnight and sacrificed by decapitation. Blood was collected in a tube containing potassium oxalate and sodium fluoride for the estimation of blood glucose and the plasma was separated for the estimation of insulin. Liver, kidney and brain were dissected out, patted dry and weighed.

Analytical Methods
Blood glucose was estimated colorimetrically using commercial diagnostic kits (Sigma Diagnostics (I) Pvt Ltd, Baroda, India) [16]. Plasma insulin was assayed by ELISA using a Boehringer-Mannheim kit with an ES300 Boehringer analyzer (Mannheim, Germany).
Fatty acid composition was performed according to the method of Morrision and Smith [17]. Fatty acid analysis was performed using a Tracer 540 gas chromatograph equipped with a column 2 cm long × 2 mm internal diameter, packed with 10% Cilar on chromosorb W, 80/100 mesh. Fatty acids separated were identified by the comparison of retention times with those obtained by the separation of a mixture of standard fatty acids. Measurements of peak areas and data processing were carried out by electronic integrator. Individual fatty acids were expressed as percentage of total fatty acids of 100mg tissue.

Histopathological study
The liver, kidney and pancreas samples fixed for 48h in 10% formal-saline were dehydrated by passing successfully in different mixture of ethyl alcohol – water, cleaned in xylene and embedded in paraffin. Sections of liver and kidney (4-5 m thick) were prepared and then stained with

hematoxylin and eosin dye, which mounted in neutral deparaffinated xylene (DPX) medium for microscopic observations.

Statistical analysis

The data for various biochemical parameters were analyzed using analysis of variance (ANOVA), and the group means were compared by Duncan's multiple range test (DMRT). Values were considered statistically significant if $p < 0.05$ [18].

3. RESULTS

Fig.1 shows the level of plasma glucose and plasma insulin of different experimental groups. The diabetic control rats showed a significant increase in the level of plasma glucose with significant decrease in the level of plasma insulin. Oral administration of CFEt to diabetic rats significantly reversed the above biochemical changes. In our previous study, [13,14,15] we have reported that CFEt at 0.45 mg/kg body weight showed better effect than 0.15 and 0.30 mg/kg body weight, therefore the 0.45 mg/kg body weight was used in this study. In agreement with these results, the present study also showed that the administration of CFEt and glibenclamide significantly improved the plasma glucose and plasma insulin levels. The CFEt administration showed more effective than glibenclamide.

Table 1, 2 and 3 shows the changes in the fatty acid composition in liver, kidney and brain of control and experimental rats. There was a significant increase in the palmitic acid (16:0), stearic acid (18:0) and oleic acid (18:1) in liver, kidney and brain of STZ diabetic rats. In contrast there was significant decrease in the concentration of linolenic acid (18:3) and arachidonic acid (20:4) in tissues of diabetic rats. In diabetic rats treated with CFEt and glibenclamide, the concentration of palmitic acid, stearic acid and oleic acid decreased whereas linolenic acid and arachidonic acid were increased

Histopathological observations in liver, kidney and pancreas of normal and experimental rats

Liver

Histopathological section of diabetic control rats liver showed portal triad with mild inflammation and cell infiltration, sinusoidal congestion and fatty degeneration in the form of fat lake and fatty change predominantly microvesicular type (Fig. 2B-D). Diabetic rats treated with 0.15 and 0.30 mg/kg body weight of CFEt revealed focal granuloma with macrovesicular fatty generation and mild sinusoidal dilatation and congestion (Fig. 2E and F). Administration of 0.45 mg/kg body weight of CFEt to diabetic rats showed sinusoidal dilatation and focal kupffer cell hyperplasia (Fig. 2H). Treatment of diabetic rats with 0.45 mg/kg body weight of CFEt documented mild portal inflammation (Fig. 2G).

Doses of 50 and 100 mg/kg of CFEt caused a decrease in the glycemia however, they showed liver damage at lower doses, which may be due to decreased effect of CFEt to protect the tissue against STZ-induced toxicity. Higher dose of CFEt 0.45 mg/kg, although caused a significant decrease in blood glucose showed liver damage that might be due to some toxic effect, by the presence of some other substances, which hide the hypoglycemic effects with damage to liver cells. 0.45 mg/kg of CFEt showed reduced liver damage.

Kidney

Kidney of diabetic control rats (Fig. 3 B-D) showed fatty infiltration, parenchymal inflammation and haemorrhages. Diabetic rats treated with 0.15, 0.30 and 0.45 mg/kg of CFEt (Fig. 3 E, F, H and I) revealed parenchymal inflammation, fatty infiltration, necrotic areas and cloudy swelling of tubules, whereas treatment with 0.45 mg/kg CFEt (Fig. 2G) showed mild parenchymal inflammation.

The histological evidence of diabetic control rats suggest that structural alterations at the end of 3 weeks are due to STZ-induced free radical generation quite early in diabetes. Damage to the kidney was significantly reduced in diabetic rats treated with 200 mg/kg of CFEt. CFEt at 0.15, 0.30and 0.45 mg/kg caused damage to kidney of diabetic rats whereas 0.45 mg/kg of CFEt reduced the toxic effects of STZ.

Pancreas

Diabetic control rats pancreas exhibited fatty infiltration of islets and shrinkage (Fig. 4B). Administration of CFEt at a doses of 0.15, 0.30 and 0.45 mg/kg (Fig. 4C, D and F) showed marked reduction in fatty changes of the islets with islet shrinkage, parenchymal inflammation and necrosis, whereas diabetic rats treated with 0.45 mg/kg CFEt (Fig. 4E) revealed near normal appearance of islets. The shrinkage of islets in diabetic control rats and diabetic rats treated with 0.15, 0.30 and 0.45 mg/kg CFEt may be due to excessive destruction of islets by STZ that specifically damages islets. In addition, the above doses of CFEt were not able to counteract the effect of STZ. CFEt at 0.45 mg/kg exhibited normal islets, which is probably due to the ability of it to withstand the detrimental effect of STZ at that concentration and protection offered by it to □-cells leading to increased insulin secretion. Thus in addition to blood glucose lowering effect, histopathological observations also supports the notion that CFEt at 0.45 mg/kg produced significant antihyperglycemic activity by protecting the tissues against STZ action.

4. DISCUSSION

Diabetes mellitus is a chronic metabolic disorder characterized by abnormalities in carbohydrate and lipid metabolism [19], which leads to hyperglycemia and hyperlipidemia [20]. The relationship between diabetes and hyperlipidemia is a well-recognized phenomenon. Insulin deficiency/insulin resistance is considered to be a significant pathogenic factor in diabetes mellitus [21] and an obvious target for antidiabetic medications [22]. Hyperlipidemia in diabetes mellitus is characterized by elevated levels of cholesterol (TC), triglycerides (TG), phospholipids (PL) and changes in lipoprotein composition [23]. These alterations may be relevant in explaining atleast inpart the increased predisposition of diabetes to atherosclerosis [24].

Hyperlipidemia in diabetes certainly contributes to the high prevalence of accelerated atherosclerosis and coronary artery disease [25]. Coronary artery disease, as a result of premature atherosclerosis is a major cause of death both in type 1 and type 2 diabetes [26]. It has been suggested that individuals possessing abnormalities in circulating lipids and glucose have strong tendency to develop diabetes [27].
In the present study, we have observed a marked alteration in the fatty acid composition of total lipids in the liver, kidney and brain tissues. There was an increase in the palmitic acid (16:0) and stearic acid (18:0) in the tissues of diabetic rats. This observation coincides with the previous report, which showed that there is a preferential synthesis of stearic acid and total saturated fatty acids in type 1 diabetic patients [28]. Administration of CFEt to diabetic rats significantly decreased the concentration of stearic acid and palmitic acid in various tissues. This may represent an attempt by CFEt to minimize the toxicity of fatty acid ethyl esters formed from saturated fatty and ethyl ester species.

In diabetic rats, the concentration of oleic acid was also observed to increase significantly. This observation was correlated with an earlier study that showed an increase in concentration of oleic acid in the membrane of both type I and type II diabetic patients [29]. Similarly, an increase in the concentration of oleic acid in liver and kidney has been reported [29].

In our study we have also observed a significant decrease in linolenic acid and arachidonic acid in diabetic rat tissues. Since these are rich in polyunsaturated fatty acids, they are the major targets for reactive oxygen species (ROS) damage. The polyunsaturated fatty acids include *n*-6 and *n*-3 essential fatty acids, which are necessary for normal membrane structure and fluidity, and eicosanoid production. The common dietary sources are linoleic acid (*n*-6) and / or α-linolenic acid (*n*-3) which are further metabolized by a series of desaturation and elongation steps to produce several polyunsaturated fatty acids, including arachidonic acid (*n*-6) and eicosapentaenoic acid (*n*-3) which are major precursors of prostanoids, leukotrienes and other mediators. Diabetes reduces the rate limiting desaturation steps, particularly delta–6 desaturation that converts linoleic acid to γ-linolenic acid and α-linolenic acid to stearidonic acid. Thus, the reduced availability of essential fatty acid intermediates in diabetes is further exacerbated by increased destruction due to elevated ROS [30]. Treatment of CFEt provided a significant protection against the changes in the fatty acid composition in diabetic rats. n-6 and n-3 polyunsaturated fatty acids are known to decrease thrombosis and atherosclerosis, which lower the incidence of cardiovascular disease [31]. This effect may also be due to improved glycemic control and increased plasma insulin that allows the diabetes rats treated with CFEt to maintain the tissue fatty acid composition in normal level.

Administration of CFEt afforded a significant protection against the changes in the fatty acid composition in diabetic rats. As *n*-6 and *n*-3 polyunsaturated fatty acids are known to decrease thrombosis and atherosclerosis, which contributes to lower the incidence of cardiovascular diseases [31]. This effect may also be due to improved glycaemic control and increased plasma insulin, which allows the diabetic rats treated with CFEt to maintain the tissue fatty acid composition in normal level.

In our study, histopathological changes we observed that diabetic control rat's causes portal triad with mild inflammation and cell infiltration; Sinusoidal congestion in the liver and parenchymal inflammation; haemorrhages in the kidney. The reaction is provoked by the increased production of highly reactive intermediates of STZ, which are normally detoxified by endogenous GSH but when present in excess, can deplete GSH stores, allowing the reactive intermediate to react with and destroy hepatic, renal cells [32]. The above pathological changes were reduced in diabetic rats treated with THC and curcumin. The histological evidence of diabetic control rats suggest that structural alterations at the end of 45 days are due to STZ-induced free radical generation quite early in diabetes. Thus in addition to blood glucose lowering effect, histopathological observations also supports the notion that THC and curcumin at 80 mg/kg produced significant antihyperglycemic activity by protecting the tissues against STZ

action. The protective effect of THC was more prominent compared with curcumin.

In conclusion, the present investigation shows that the administration of CFEt and glibenclamide to STZ diabetic rats decreases tissue lipids and maintains the fatty acid composition in normal level.

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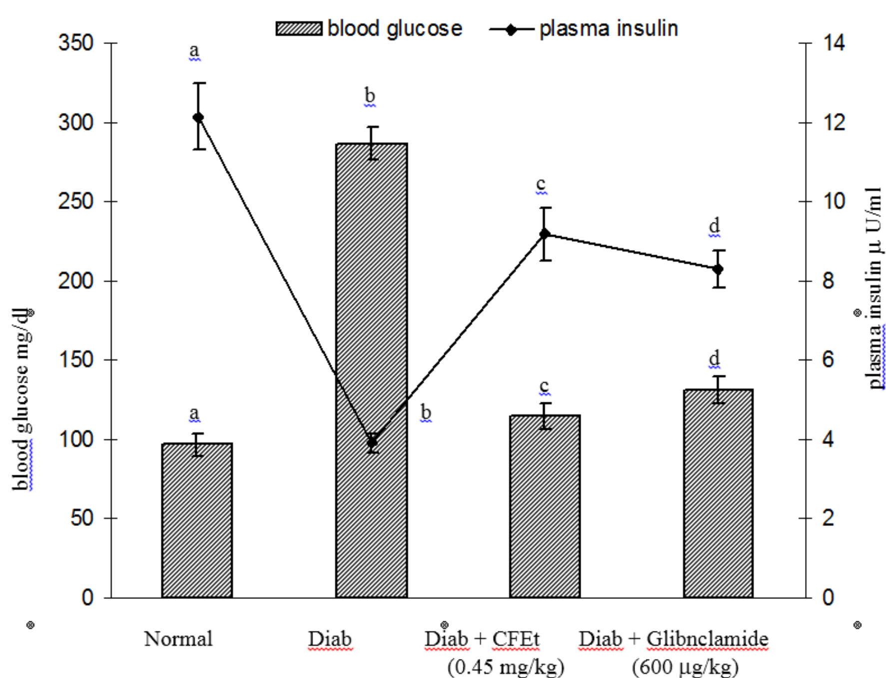


Figure 1. Effect of CFEt on the levels of blood glucose and plasma insulin in normal and experimental rats

Values are given as mean ± S.D for 6 rats in each group.
Values not sharing a common superscript letter differ significantly at $p<0.05$ (DMRT).

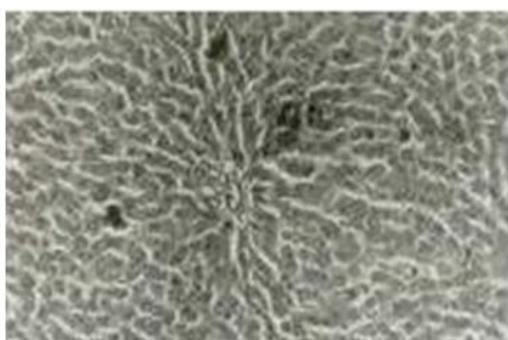


Figure 2 A. Normal rats liver H&E x 20

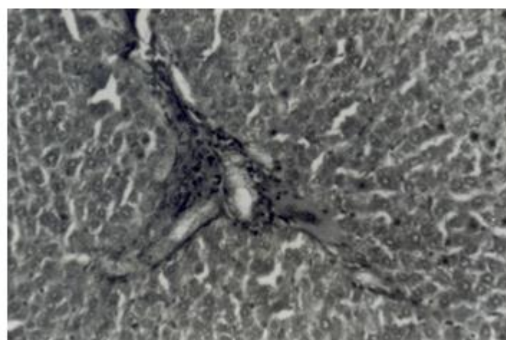


Figure 2 B. Diabetic control rats liver H&E x 20
Portal triad with mild inflammation and cell infiltration

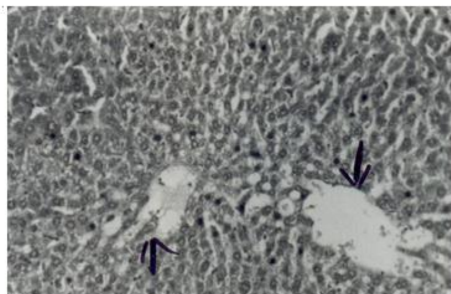


Figure 2 C. Diabetic control rats liver H&E x 20
Sinusoidal congestion and fatty degeneration in the form of fat lake (→)

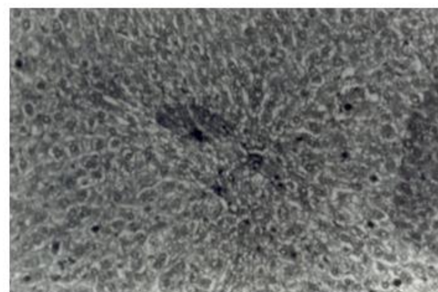


Figure 2 D. Diabetic control rats liver H&E x 20
Another area of fatty change predominantly microvesicular

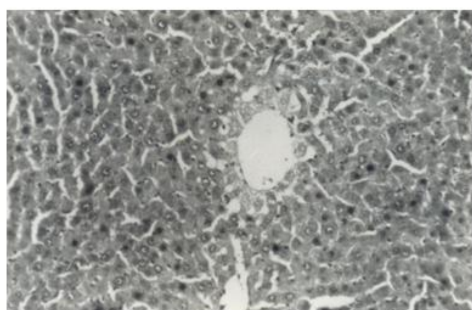


Figure 2 E. Diabetic + CFEt (0.15 mg) treated rats liver H&E x 20
Focal granuloma and macrovesicular fatty degeneration

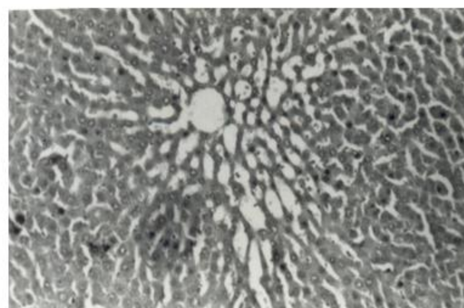
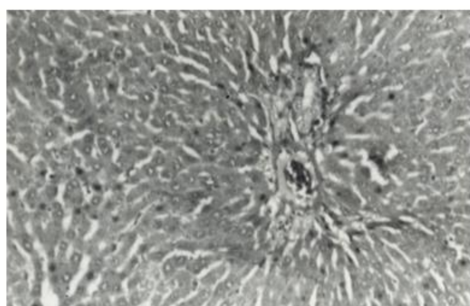


Figure 2 F. Diabetic + CFEt (0.30 mg) treated rats liver H&E x 20
Mild sinusoidal dilatation and congestion



2 G. Diabetic + CFEt (0.45 mg) treated Figure rats liver H&E x 20
Mild portal inflammation with near normal appearance

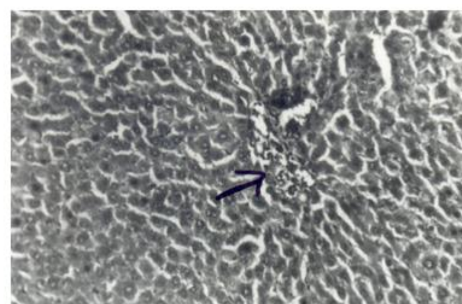


Figure 2 H. Diabetic + glibenclamide (0.45 mg) treated rats liver H&E x 20
Mild sinusoidal dilatation and focal kupffer cell hyperplasia

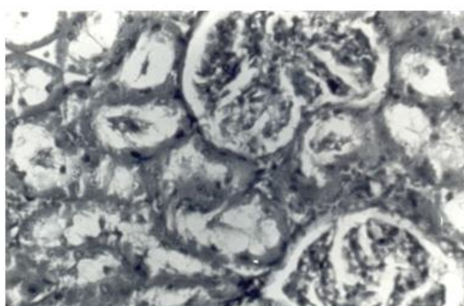


Figure 3 A. Normal rats kidney H&E x 20

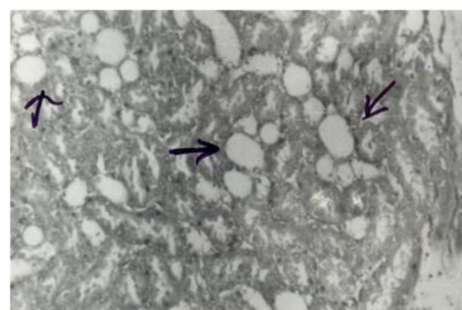


Figure 3 B. Diabetic control rats kidney H&E x 20
Fatty infiltration (→)

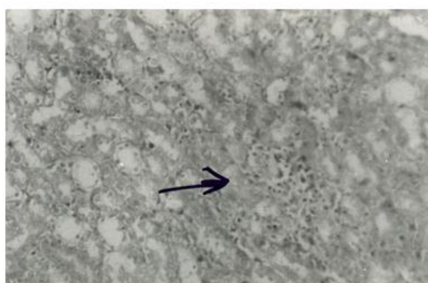


Figure 3 C. Diabetic control rats kidney H&E x 20

Parenchymal inflammation (→)

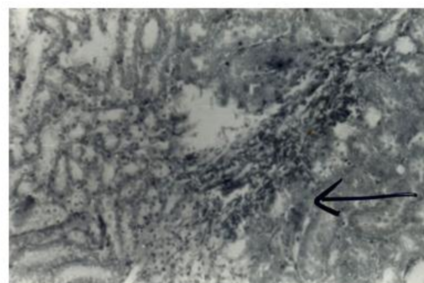


Figure 3 D. Diabetic control rats kidney H&E x 20

Haemorrhages (→)

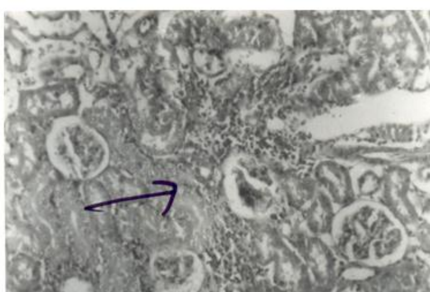


Figure 3 E. Diabetic + CFEt (0.15 mg) treated rats kidney H&E x 20

Parenchymal inflammation (→)

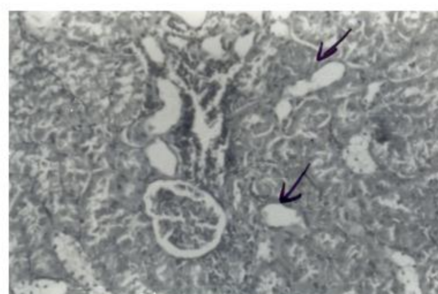


Figure 3 F. Diabetic + CFEt(0.30 mg) treated rats kidney H&E x 20

Fatty infiltration (→)

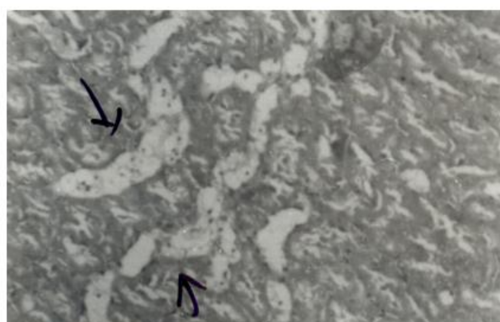


Figure 3 I. Diabetic + glibenclamide treated rats kidney H&E x 20

Cloudy swelling of tubules (→)

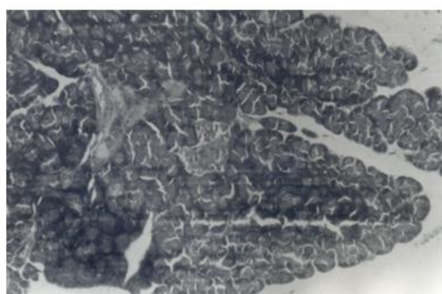


Figure 4 A. Normal rats pancreas H&E x 20

Pancreas showing -islets (→)

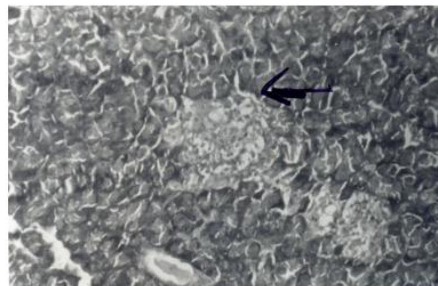


Figure 4 B. Diabetic control rats pancreas H&E x 20

Fatty infiltration of islet cells and shrinkage (→)

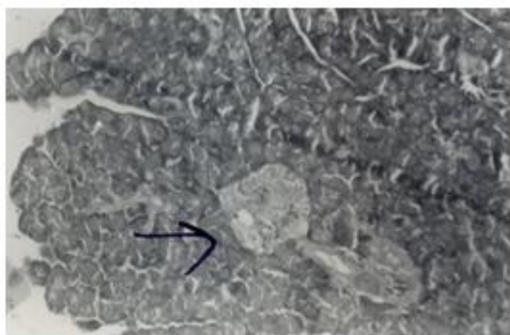


Figure 4 C. Diabetic + CFEt (0.15 mg) treated rats pancreas H&E x 20
Marked reduction in fatty infiltration of islets (→)

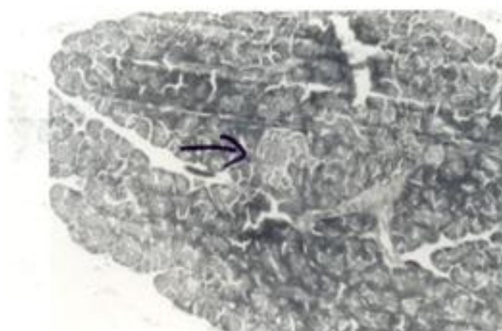


Figure 4 D. Diabetic + CFEt (0.30 mg) treated rats pancreas H&E x 20
Islet shrinkage (→)

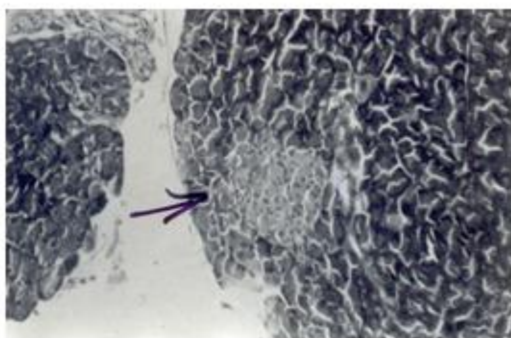


Figure 4 E. Diabetic + CFEt (0.30mg) treated rats pancreas H&E x 20
Normal appearance of islets (→)

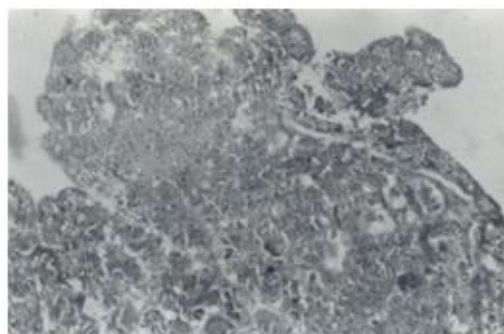


Figure 4 F. Diabetic +CFEt (0.45 mg) treated rats pancreas H&E x 20
Parenchymal inflammation and necrosis

Table 1. Changes in the fatty acid composition of total liver lipids in normal and experimental rats

Group	Percentage of fatty acid / 100 mg tissue				
	16:0 Palmitic acid	18:0 Stearic acid	18:1 Oleic acid	18:3 Linolenic acid	20:4 Arachidonic acid
Normal	21.56 ± 1.21[a]	11.56 ± 0.71[a]	7.55 ± 0.45[a]	6.68 ± 0.36[a]	21.02 ± 1.15[a]
Diabetic Control	29.53 ± 1.85[b]	18.31 ± 1.26[b]	14.02 ± 0.85[b]	2.92 ± 0.15[b]	12.62 ± 0.71[b]
Diabetic + CFEt	22.87 ± 1.41[ac]	14.36 ± 0.63[c]	9.47 ± 0.53[c]	4.71 ± 0.31[c]	18.61 ± 1.19[c]
Diabetic + Glibenclamide	25.47 ± 1.26[c]	13.36± 0.66[d]	11.27 ± 0.58[d]	3.45 ± 0.18[d]	16.58 ± 0.59[d]

Values are given as mean ± S.D from ten rats in each group.
Values not sharing a common superscript letter differ significantly at $p<0.05$ (DMRT).

Table 2. Changes in the fatty acid composition of total kidney lipids in normal and experimental rats

Group	Percentage of fatty acid / 100 mg tissue				
	16:0 Palmitic acid	18:0 Stearic acid	18:1 Oleic acid	18:3 Linolenic acid	20:4 Arachidonic acid
Normal	23.66 ± 1.43^a	13.67 ± 0.57^a	5.98 ± 0.39^a	6.98 ± 0.39^a	13.01 ± 0.66^a
Diabetic Control	32.73 ± 2.15^b	23.56 ± 1.53^b	12.02 ± 0.55^b	2.79 ± 0.25^b	5.78 ± 0.41^b
Diabetic + CFEt	26.39 ± 1.53^c	16.61 ± 1.02^c	7.89 ± 0.48^c	4.91 ± 0.33^c	10.89 ± 0.75^c
Diabetic + Glibenclamide	28.76 ± 1.43^d	16.43 ± 0.87^d	9.84 ± 0.48^d	3.66 ± 0.17^d	9.48 ± 0.52^d

Values are given as mean ± S.D from ten rats in each group.
Values not sharing a common superscript letter differ significantly at $p<0.05$ (DMRT).

Table 3. Changes in the fatty acid composition of total brain lipids in normal and experimental rats

Group	Percentage of fatty acid / 100 mg tissue				
	16:0 Palmitic acid	18:0 Stearic acid	18:1 Oelic acid	18:3 Linolenic acid	20:4 Arachidonic acid
Normal	23.12 ± 1.05^a	12.99 ± 1.07^a	9.69 ± 0.47^a	8.58 ± 0.47^a	16.58 ± 0.56^a
Diabetic Control	36.87 ± 2.47^b	21.89 ± 1.58^b	16.87 ± 1.19^b	3.58 ± 0.22^b	7.68 ± 0.42^b
Diabetic + CFEt	26.42 ± 1.51^c	14.77 ± 0.53^c	11.68 ± 0.61^c	6.35 ± 0.47^c	14.36 ± 0.59^c
Diabetic + Glibenclamide	30.01 ± 1.48^d	16.99 ± 0.66^d	13.55 ± 0.58^d	5.39 ± 0.11^d	12.89 ± 0.65^d

Values are given as mean ± S.D from ten rats in each group.
Values not sharing a common superscript letter differ significantly at $p<0.05$ (DMRT).