

Antioxidant and Antidiabetic Properties of *Tetrapleura tetraptera* (Schum. and Thonn.) Taub. Whole FruitOgunlakin, Daniel Akingbolabo^{1*} and Mubo Adeola Sonibare²¹Phytomedicine, Molecular Toxicology, and Computational Biochemistry Research Laboratory (PMTCB-RL), Biochemistry Programmes, Bowen University, Iwo, 232101, Nigeria.²Department of Pharmacognosy, Faculty of Pharmacy, University of Ibadan, Ibadan. Nigeria.**Abstract**

The objective of this study is to investigate toxicity, phytochemical constituents, antioxidant and antidiabetic activities of *Tetrapleura tetraptera* whole fruits. Phytochemical screening of the extract identified the presence of alkaloid, saponin and flavonoid. The total phenolic contents of methanol extract, hexane, chloroform and ethyl acetate fractions are of 38.63 ± 8.11 , 52.41 ± 1.92 , 8.16 ± 0.36 and 5.16 ± 0.56 mg gallic acid equivalent/g of extract, respectively, while methanol extract, hexane, chloroform and ethyl acetate fractions had total flavonoid contents of 6.87 ± 0.81 , 7.44 ± 0.78 , 12.38 ± 0.72 and 9.32 ± 0.37 mg quercetin equivalent/g of extract, respectively. The IC_{50} for DPPH radical scavenging activity of methanol extract, hexane, chloroform and ethyl acetate fractions are 192 ± 2.01 , 226.67 ± 1.40 , 73.33 ± 1.86 and $127.33 \pm 3.18 \mu\text{g/mL}$ respectively. The IC_{50} value of ascorbic acid was $18.44 \pm 1.20 \mu\text{g/mL}$. The methanol extract of *T. tetraptera* fruit (1g/kg bw.) produced a significant ($p < 0.05$) reduction of fasting blood glucose level. There was an increase in the plasma level of ALT in *T. tetraptera* treated rats compared to the control. According to histopathological examinations of the pancreas of diabetic rats given methanol extract treatment, the pancreatic islets' size was noticeably reduced, the islets of Langerhans' outlines were atypical, and there were numerous hemorrhages throughout the organ. These results indicate that the fruit of *T. tetraptera* may be a source for future oral hypoglycemic drug development.

Keywords: *Tetrapleura tetraptera*, Alloxan, Diabetes, Toxicity, Antioxidant, Phytochemical screening**Abbreviation**

DPPH: 2, 2'-diphenyl-1-picrylhydrazyl; IC: inhibitory concentration; DM: Diabetes mellitus; FHI: Forest Herbarium, Ibadan; DPHUI: Department of Pharmacognosy Herbarium, University of Ibadan; GAE: gallic acid equivalent; QE: quercetin equivalent; TC: Total cholesterol; HDL: high density lipoprotein; TRIG: Triglyceride; ALT: Alanine aminotransferase; AST: Aspartate aminotransferase; ALP: Alkaline phosphatase.

*Corresponding authors: E-mail addresses: gbolaogunlakin@gmail.com; Tel. +234 703 788 3049**Introduction**

Diabetes mellitus (DM) is a condition in which the pancreas either fails to make enough insulin or in which the body's cells fail to react to insulin as they should. It is a metabolic disorder marked by changes in the way that proteins, lipids, and carbs are metabolized as a result of errors in insulin secretion or action, or both.

A lack of glucose homeostasis is its main feature. Due to a complete lack of insulin in the serum, it is marked by high blood sugar levels, hyperlipemia, an imbalance of nitrogen in the body, as well as intermittent ketonemia [1–9].

Due to the fast-increasing incidence of the condition, the World Health Organization [10] predicts that by 2030, there will have been roughly twice as many adults worldwide who had diabetes. By 2025, researchers project that there will be a stunning 53.1 million people worldwide who have diabetes, a 64% increase [11–13]. Diabetes mellitus is becoming more prevalent and in the USA it is presently the seventh most prevalent cause of death. Every fifteen years, the population of diabetics will double if the present growth rate of six percent per year holds. Diabetes will cause neurological, microvascular, or macrovascular issues in more than 75% of patients [14–20].

However, the use of oral hypoglycaemic medications to treat diabetes is constrained due to their unfavorable side effects, which include potential hypoglycemia (e.g., sulfonylurea), weight gain (sulfonylurea, meglitinides, and thiazolidinediones), gastrointestinal discomfort (α -glucosidase inhibitors, and alpha-amylase inhibitors), and lactic acidosis (metformin) [21–26]. Finding alternative plants to cure diabetes that has fewer or no side effects has become essential as a result of the drawbacks of using oral hypoglycemic medications. Plants have been used as medicines to cure illness for a very long time [27–29]. In almost all civilizations, medicinal plants have been used as a form of therapy. It is estimated that eighty to eighty-five percent of people in industrialized as well as developing nations depend on traditional medical practices for the majority of their healthcare needs [30–34]. Additionally, it is expected that a significant portion of traditional

therapy will involve the use of extracts from plants or their bioactive substances.

Tetrapleura tetraptera Taub is a hardy perennial tree in the Fabaceae family. It has a solitary stem, dark green leaves, a large wooden base, and spreading branches. Native to most of equatorial Africa, the plant is most prevalent in the regions of West, Central, and East Africa that are covered in rainforests. The plant's fruits are mature, four-winged pods that are 15–27 centimeters long and 4–5 cm wide. They develop a dark brown hue when completely ripe. The fruit consists of a small number of tiny, brownish-black seeds and mushy flesh. Its insect-repelling abilities have been linked to the fruit's fragrant, distinctively pungent aroma [35]. The fruit has been shown to have anticonvulsant, molluscicidal, cardiovascular, hypotensive, anti-ulcerative, neuromuscular, anti-inflammatory, and anti-microbial effects. It is used to treat convulsions, diabetes, leprosy, inflammation, and rheumatic aches [36]. No research has been done to assess whether the whole fruit has anti-diabetic qualities although it is used in pepper soup and soup for new mothers in the southwest of Nigeria [37–40]. This study was conducted to evaluate the toxicity, antioxidant, and anti-diabetic effects of *Tetrapleura tetraptera* fruits.

Materials and methods

Plant Collection, Identification and Authentication

On April 2013, *T. tetrapleura* fruits were harvested in the Wasinmin hamlet of Osun state, Ayedaade Local Government Area of Osun state. The Forest Herbarium in Ibadan (FHI) identified and authenticated the plant.

Voucher specimens were placed in the Department of Pharmacognosy Herbarium at the University of Ibadan (DPHUI) and the Forest Herbarium, Ibadan (FHI).

Extraction and partitioning of plant materials

The *T. tetrapluera* fruits were air-dried for 21 days. The plant materials were processed into a coarse powder using an electric grinding mill. The powdered components were macerated in methanol for three days at room temperature with intermittent stirring and shaking in an airtight, clean flat-bottomed container. The extract was then filtered using a new cotton plug and Whatman filter paper. The filtrate was concentrated in vacuo using a rotating evaporator. The weight of the crude extract was determined, and the yield percent was calculated. The modified method of Kupchan and Tsou [41] as well as Wagenen et al. [42] was used to partition the extract into hexane, DCM, and ethyl acetate fractions.

Phytochemical screening

The fruit powder was subjected to phytochemical assays using the protocols outlined by Sofowora [43], Trease and Evans [44], and Harborne [45].

Estimation of Total Phenolic Content

Using the method described by Nabavi et al. [46], the extract's and fractions' total phenolic concentrations were evaluated. The Folin-Ciocalteu reagent reduces materials containing polyphenols, producing a blue colour. A calibration curve for gallic acid was made by combining 2.5 mL of the Folin-Ciocalteu reagent (10-fold reduced), 2.5 mL of sodium carbonate (75 g/L), as well as 0.5 mL aliquots

of solutions containing 12.5, 25, 50, 100, and 200 mg/mL methanolic gallic acid. This made it possible to calculate the phenolic concentration of the extract. After a 30-minute incubation period at room temperature, the mixture was analyzed with a UV/Visible spectrophotometer model 752s to ascertain the level of phenol present. The overall phenolic content was measured in milligrams of gallic acid equivalent per gram of extract.

Estimation of Total Flavonoid Content

The amount of flavonoid was measured using the colorimetric aluminum chloride method [47]. The material (0.5 mL, 200 mg/mL) was mixed in 1.5 mL methanol, 0.1 mL 10% aluminum chloride, 0.1 mL 1 M potassium acetate, and 2.8 mL distilled water. After the mixture was kept at room temperature (28 to 30 °C) for 30 minutes, the reaction mixture's absorbance at 415 nm was measured in the lab using a double-beam UV/Visible spectrophotometer (USA). The calibration curve was produced using methanol solutions containing quercetin at doses of 12.5 to 200 mg/mL. Three independent measurements were made to determine the quantity of flavonoids in each gram of extract, which were then converted to milligrams of quercetin equivalent (QE).

DPPH radical scavenging assay

To ascertain the extract's capacity to scavenge free radicals and the effectiveness of ascorbic acid as a positive control, Susanti et al.'s method [48] was applied with a few slight modifications. At different concentrations (100, 50, 25, 12.5, 6.25, 3.125, and 1.625 g/mL), three milliliters of newly made DPPH solution

(0.1 mM in methanol) were combined with two milliliters of the extract and the control. The mixture's absorbance at 517 nm was measured using a 752s spectrum lab UV/Visible spectrometer after 30 minutes of incubation at the ambient temperature in the darkness. Every experiment was repeated three times in total. How much DPPH changes color from purple to yellow indicates how well the extract scavenges free radical. The following equation was used to determine the percentage inhibition of DPPH free radical scavenging activity:

$$\% \text{ inhibition} = \left[\frac{\text{absorbance of control} - \text{absorbance of test sample}}{\text{absorbance of control}} \right] \times 100$$

The linear regression curve was used to get the IC₅₀ value, which was then utilized to express each sample's antioxidant activity. The IC₅₀ value is the micromolar concentration required to reduce the production of DPPH radicals by 50%.

Experimental protocols

Animals

Male albino rats of the Wistar strain, weighing between 150 and 200 g, were employed for the investigation. Commercial grower's mash pellets were used to feed the rats. Except for the final 12 to 15 hours before the experiment's end, they were kept at room temperature and fed ad libitum on growers' mash and tap water. The animals were kept in plastic cages at room temperature with a 12-hour light/12-hour dark cycle. Before the start of the experiment and after it was over, the animal weights were noted.

Toxicity study

Acute toxicity study was performed according to standard procedure [49].

Antidiabetic assay

To induce hyperglycemia in rats that had fasted the previous night, an intraperitoneal injection of a freshly prepared, 150 mg/kg aqueous solution of alloxan monohydrate was administered. A 48-hour fasting blood glucose level of 140 mg/dL or greater qualified each animal for inclusion in this investigation. Those animals that did not develop hyperglycemia 48 hours after getting an injection of alloxan were replaced with new ones. The animals were divided into five groups of five rats each once it was found that they had diabetes. Rats in Groups I and II had diabetes and served as the control and diabetic groups, respectively, whereas Groups III and IV received treatment with glibenclamide and 1000 mg/kg of *T. tetrapluera* fruit methanol extract, respectively. The dosage of the extract used was within a safe range (1000mg/kg body weight), whereas glibenclamide, the standard treatment, was given at a dose of 1 mg/kg.

Blood glucose determination

After the injection of alloxan, treatment with plant extracts began 48 hours later. Using an Accu Chek glucometer, the glucose oxidase technique was used to measure fasting blood sugar (Roche diagnostics, Germany). The rat's tail was promptly severed with a sterile blade and a drop of blood was squeezed onto the test region of the strip that was placed into the glucometer. The animals were seen to have a 12-hour fast before each glucose reading. On days 0, 1, 4, and 7 of the experiment, all rats'

body weights and fasting blood glucose levels were recorded.

Collection of blood sample

Rats were euthanized after the experimental times. On day 7, rodents that had not eaten all night were punctured in the heart to obtain blood. By centrifuging the blood samples at 5000 speed for 10 minutes, plasma and serum were extracted from the blood samples. Then, until analysis, these materials were kept refrigerated.

Biochemical analysis

The plasma levels of aspartate aminotransferase (AST), alkaline phosphatase (ALP), high-density lipoprotein (HDL), alanine aminotransferase (ALT), triglyceride (TRIG), and alanine aminotransferase (AST), as well as their activities, were assessed using standard assay kits produced by Randox Laboratories. Serum concentrations of triglycerides (TRIG) and high-density lipoprotein (HDL) were assessed. According to the kit instructions, the calorimetric determination of HDL serum concentration was made using a spectrophotometer instrument set at 520 nm (Randox Co., UK). According to the instructions included with the kits, enzymatic methods were used to measure the serum amounts of TG and TC (Randox Co., UK). The absorbance of the examined materials was assessed using a spectrophotometer calibrated at 546 nm. For the AST, ALT, and ALP test samples, the absorbance was measured at 546 nm, and 405 nm.

Histopathological study

The rats were sedated on day seven of the experiment, and the pancreas was extracted.

The animals were then preserved in 10% formaldehyde. Hematoxylin and eosin was used to stain the obtained paraffin slices of tissue that had undergone autotechnicon tissue processing, which were 5-micron thick and placed on slides [51]. The quality of stained sections was assessed (morphologically). Histological studies' photomicrographs were taken.

Statistical analysis

The results were expressed as mean±S.E.M., the significant of various treatments were calculated (Student's *t*-test) using SPSS 16.0 and considered statistically significant at $p < 0.05$.

Results

Extraction, acute toxicity and phytochemical screening

T. tetraptera fruit produced a yield of 43.8%. After 14 days of monitoring, none of the rats given the extracts at various dosages up to 5000 mg/kg demonstrated death or audible adverse effects. Alkaloids, flavonoids, saponins, and tannins were found in *T. tetraptera* fruit extract after a phytochemical examination (Table 1).

Antioxidant activity

The amount of flavonoids and other phenolic compounds present in the methanolic extracts of *T. tetraptera* fruit is depicted in Figures 1 and 2. The total phenolic contents of the *T. tetraptera* fruit methanol extract, as well as those of the hexane, chloroform, and ethyl acetate fractions, are 38.63 ± 8.11 mg gallic acid equivalent/g of extract and 6.87 ± 0.81 mg quercetin equivalent/g of extract, respectively. The *T. tetraptera* fruit extract has DPPH radical-scavenging activity (presented as IC₅₀

values) of 192 ± 2.01 , 226.67 ± 1.40 , 73.33 ± 1.86 , and 18.44 ± 1.20 $\mu\text{g/mL}$, respectively (Table 2). The IC_{50} for ascorbic acid is 18.44 ± 1.20 $\mu\text{g/mL}$.

Antidiabetic activity

Table 3 shows that compared to glibenclamide (which dropped FBGL by 31.9%), a fruit extract from *T. tetraptera* at 1000 mg/kg body weight decreased FBGL by 2.1%.

After a 7-day treatment period, the weight of Group I grew, but the weights of Groups II, III, and IV fell, with percentage drops of 7.2%, 10.6%, and 21.4%, respectively. Following seven days of therapy, there was weight growth that was correlated with an improvement in the pancreas' health (Table 3). *T. tetraptera* fruit extract's antidiabetic effects on lowering blood sugar levels were substantial ($p < 0.05$). After receiving treatment with 1000 mg/kg of *T. tetraptera* fruit extract, the abnormal serum lipid profile was corrected in Group IV (Figure 3). When compared to the control, the plasma level of ALT increased in the *T. tetraptera* group. Moreover, AST activity significantly ($p < 0.05$) increased while ALP activity was marginally ($p < 0.05$) reduced compared to normal (Figure 3).

The extract-treated groups displayed a return to normal cellular population and islet size with hyperplasia, as illustrated in Figure 4. A normal islet of the Langerhans cellular population was evident in the pancreas' histopathological slice from the healthy control rat (normal-sized pancreatic islets with regular outlines; the islet cells have normal nucleus and cytoplasm; normal exocrine acini and pancreatic ducts; no congestion of blood vessels; and no visible lesion). Non-treated diabetic rats exhibited

anomalies in their pancreas, including reduced cellular density, alterations in the islet of Langerhans, and extravagated blood in exocrine pancreatic tissue. When diabetic rats were given *T. tetraptera's* methanolic extract, they showed a striking reduction in the size of their pancreatic islets, irregular shapes in their islets of Langerhans, and extensive hemorrhages (Figure 4).

Discussion

After 14 days of monitoring, none of the rats given various doses of the extracts up to 5000 mg/kg demonstrated death or audible adverse effects. According to the results, the plant extract has a low level of toxicity. As a result, the trial dose used, 1000 mg/kg p.o., was within the acceptable range.

Food products made from plant sources frequently contain flavonoids and other phenols, which have been demonstrated to have strong antioxidant properties [52–56]. The antioxidative capabilities of the extracts may originate from a variety of chemicals with varying polarity, according to the data. These substances or flavonoids might be responsible for some of the antioxidative activity. According to studies [57–61], consuming more flavonoids may offer protection from a variety of human diseases. This activity is thought to be primarily caused by their redox characteristics, which are crucial for quenching singlet and triplet oxygen, adsorbing free radicals, and degrading peroxides [62–64]. Given that polyphenolic chemicals have been linked to antioxidant activity, these substances are probably what makes the extracts work [65–68]. Methyl phenolic and hydroxyl phenolic

chemicals, as well as acid, alcohol, sugar, or glycoside, may be present in methanol extracts, according to findings [69,70]. Furthermore, the results of this investigation showed that flavonoids are important components of *T. tetraptera* fruit and that their presence may help to explain some of the fruit's pharmacological effects.

Methanol extract of *T. tetraptera* fruit decreased fasting blood glucose levels (FBGL). During seven days of treatment, weight growth was seen, and this was correlated with a pancreatic condition improvement. Diabetes is characterized by hyperglycemia and dyslipidemia, which are risk factors for coronary heart disorders [73,74]. The abnormally high level of serum lipids is mostly caused by insulin-induced lipolytic hormone activities on fat depots that are uncontrolled. Normal conditions result in the activation of the triglyceride-hydrolyzing enzyme lipoprotein lipase by insulin. Furthermore, insulin deficit leads to hypertriglyceridemia in a diabetic condition and, as a result of metabolic irregularities, insulin insufficiency is also linked to hypercholesterolemia [75,76]. A rise in TC, TG and a decrease in HDL are symptoms of dyslipidemia. The smallest lipoprotein species, high-density lipoprotein (HDL), contains just a little amount of triglycerides (about 20%) and around 20% of cholesterol ester [77,78]. As a consequence of hormone-sensitive lipase activation via insulin deficiency, the abnormally elevated blood lipid concentration was mainly brought on by an increase in the mobilization of free fatty acids (FFA) from peripheral tissue. Additionally, it is

understood that elevated HMG CoA reductase activity, which may result in hyperglycemia, is linked to a rise in cholesterol synthesis [79].

Through the inhibition of HMG-CoA reductase, flavonoids derived from plants have been related to fat loss [80–82]. Furthermore, the resin-like action of saponin, which decreases serum cholesterol levels and reduces bile acid circulation in the enterohepatic system, is well known. Concurrent hypocholesterolemia is also brought on by it because the process increases the liver's capacity to transform cholesterol into bile acid. Additionally, saponins have been found to increase lipoprotein lipase activity (LPL), which is believed to help remove free fatty acids from circulation faster, thereby lowering cholesterol. It is known that they inhibit certain nutrients' absorption in the intestines, particularly cholesterol, through intraluminal physiochemical interactions. It is thought that the reason why saponins have both hemolytic and hypocholesterolemic effects is that they have a strong affinity for the aglycone moiety of membrane sterols, especially cholesterol, with which they make insoluble complexes [83,84]. This fruit extract contains saponins as well as tannins that may inhibit cholesterol esterase, stimulate fatty acid synthase, and produce triglyceride precursors like acetyl-CoA and glycerol phosphate, as well as prohibit lipids from entering the bloodstream [85–87] and prevent the formation of triglycerides altogether [88–90].

The plasma membrane marker enzyme alkaline phosphatase (ALP) serves as a sign of liver cholestasis. The liver's integrity may have been

compromised, causing the enzyme to leak into the plasma. According to Pincus and Schaffner [91], when there is substantial hepatic damage, AST and ALT are discharged into the plasma. The biomembrane lipid peroxidation, which causes the leakage of cellular components, may be the reason for the increase in hepatic marker enzymes exhibited by the alloxan-treated group [92]. Several phytochemicals found in medicinal plants' leaves, stem bark, roots, and fruits are what give them their therapeutic powers [93]. The treatment rats' blood glucose levels were considerably lowered by the *T. tetraptera* fruit extract, and the regeneration of β -cells is likely what contributed to this outcome. Alloxan causes serious harm to the islets of Langerhans cells [94]. Due to the islets of Langerhans cells being destroyed by alloxan, hyperglycemia and a sharp decline in insulin production are the results [95]. The pancreatic islet biomembranes' resistance to lipid peroxidation, as shown by the partial restoration of a normal cellular population, suggests that the *T. tetraptera* fruit could possess anti-diabetic effects.

Conclusion

No adverse effects were observed after receiving a single dose of the crude extract from *T. tetraptera* fruit in albino rats, demonstrating the extract's safety under the given conditions. Alkaloids, flavonoids, saponins, and tannins were discovered when the phytochemistry of *T. tetraptera* was examined. These compounds are known to have bioactive qualities that can help treat diabetes. The antidiabetic effects of the phytochemical elements found in *T. tetraptera* fruit, such as flavonoids and saponins, could be

responsible for the observed biochemical and anatomical modifications reported in this work. This backed up its conventional use for diabetes management. As a result, it may aid in preventing diabetes complications and may be a useful alternative to existing anti-diabetic medications.

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Conflict of interest

The authors declare that they have no conflict of interest.

Authors' contributions

The work was created by MAS and ADO. The work was either entirely or substantially reworked by MAS and ADO. The material was collected, examined, and interpreted by all authors.

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Figure legends

Figure 1: Total flavonoid content of TTCE and its fractions

Figure 2: Total phenolic content of TTCE and its fractions

Figure 3: Result of biochemical analysis of the blood samples from experimental animals

Figure 4: Histopathology of the pancreas of the experimental rats (X 400)

Table 1: Preliminary phytochemical screening result of *T. tetraptera* fruit

Test(s)	<i>T. tetraptera</i> whole fruit powder sample
1. Alkalioids	++
(a). Dragendroff	+
(b). Mayer test	
2. Anthraquinones glycosides	
(a). Borntrager test	
3. Saponins	
(a). Foam test	++
(b). Emulsion test	++
4. Tannins	
(a). Ferric chloride test	++
5. Glycoside	
(a). Salkowski's test	-
(b). Keller-Kiliani test	-
6. Flavonoids	
(a). Lead acetate test	+++

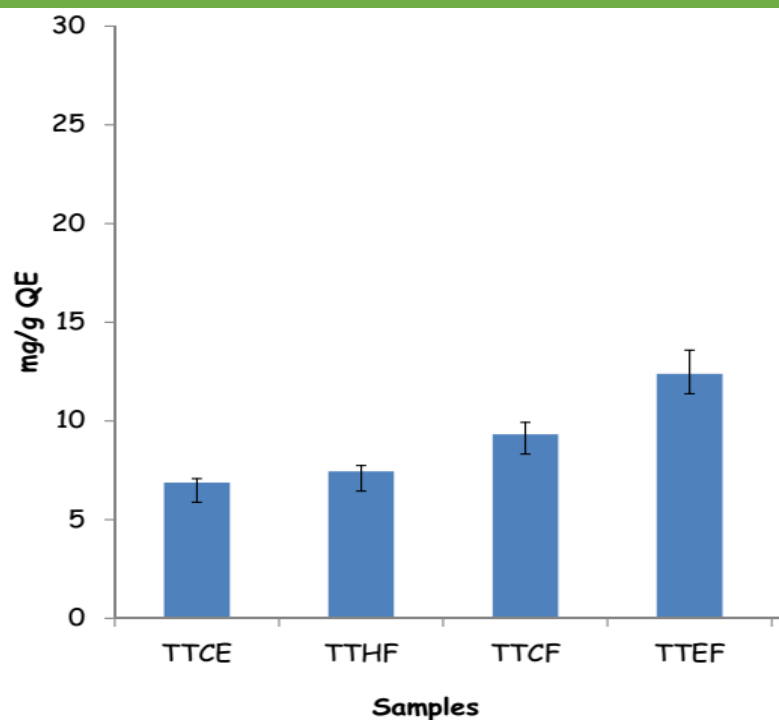


Figure 1: Total flavonoid content of TTCE and its fractions

TTCE: crude extract, TTHF: *n*-hexane fraction, TTCF: chloroform fraction, TTEF: ethyl acetate fraction

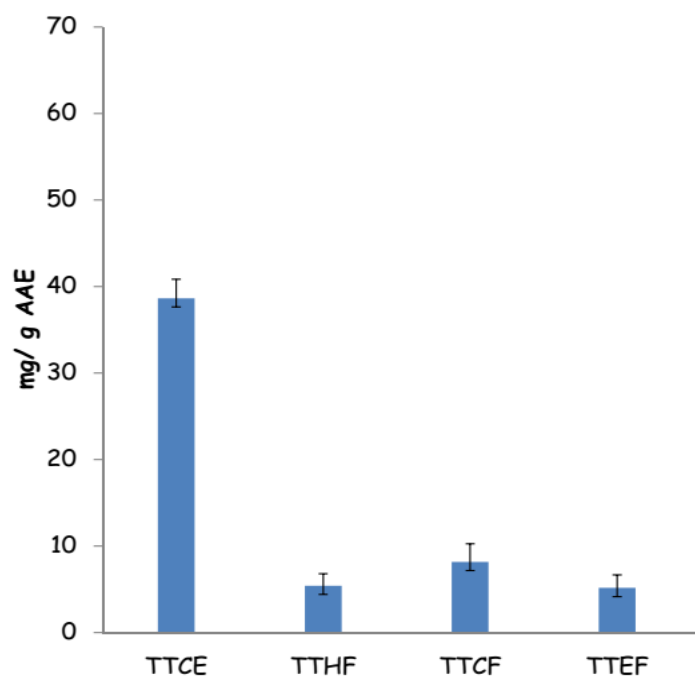


Figure 2: Total phenolic content of TTCE and its fractions

TTCE: crude extract, TTHF: *n*-hexane fraction, TTCF: chloroform fraction, TTEF: ethyl acetate fraction

Table 2: DPPH radical scavenging activity of *T. tetraptera* fruit

Samples	IC ₅₀ values (µg/mL)
TTCE	192±2.01
TTHF	226.67±1.40
TTCF	73.33±1.86
TTEF	127.33±3.18
Ascorbic acid	18.44±1.20

Values expressed as mean±SEM

TTCE = *T. tetraptera* crude extract, TTHF = *T. tetraptera* n-hexane fraction, TTCF = *T. tetraptera* chloroform fraction, TTEF = *T. tetraptera* ethyl acetate fraction

Table 3: Effect of TTME on blood glucose level (mg/dL) and body weight (g) of the experimental animals

Animal groups	0 day		1 st day		4 th day		7 th day	
	BGL	Body weight	BGL	Body weight	BGL	Body weight	BGL	Body weight
Grp I (Normal control)	93.40±4.33 ^b	150.8±0.49 ^a	100.60±2.76 ^a	150.40±0.68 ^{ab}	92.60±2.44 ^a	155.40±3.07 ^b	94.80±4.19 ^a	159.00±4.11 ^b
Grp II (UDG)	367.67±15.00 ^b	163.20±1.53 ^c	372.80±25.00 ^b	159.60±1.75 ^b	378.20±30.05 ^b	154.60 ±1.60 ^b	382.04±10.04 ^b	148.80±1.98 ^{ab}
Grp III (GM, 1 mg/Kg)	373.17±72.74 ^{ab}	160.80±6.70 ^b	298.60±73.85 ^c	145.00±11.01 ^{ab}	197.83±58.51 ^c	146.60 ±13.57 ^{ab}	254.20±58.11 ^c	143.20 ±15.93 ^{ab}
		c						
Grp IV (TTME, 1g/Kg)	479.00±35.25 ^c	152.20±1.74 ^a	539.33±31.81 ^c	138.00±3.63 ^a	445.67±53.18 ^c	133.00±5.46 ^a	469.67±34.30 ^c	128.40±7.97 ^a
		b						

Values expressed as mean±SEM; Means with the same superscript are not significantly different from each other (p<0.05). UDG = untreated diabetic group, GM = glibenclamide and TTME = *T. tetraptera* fruit methanol extract.

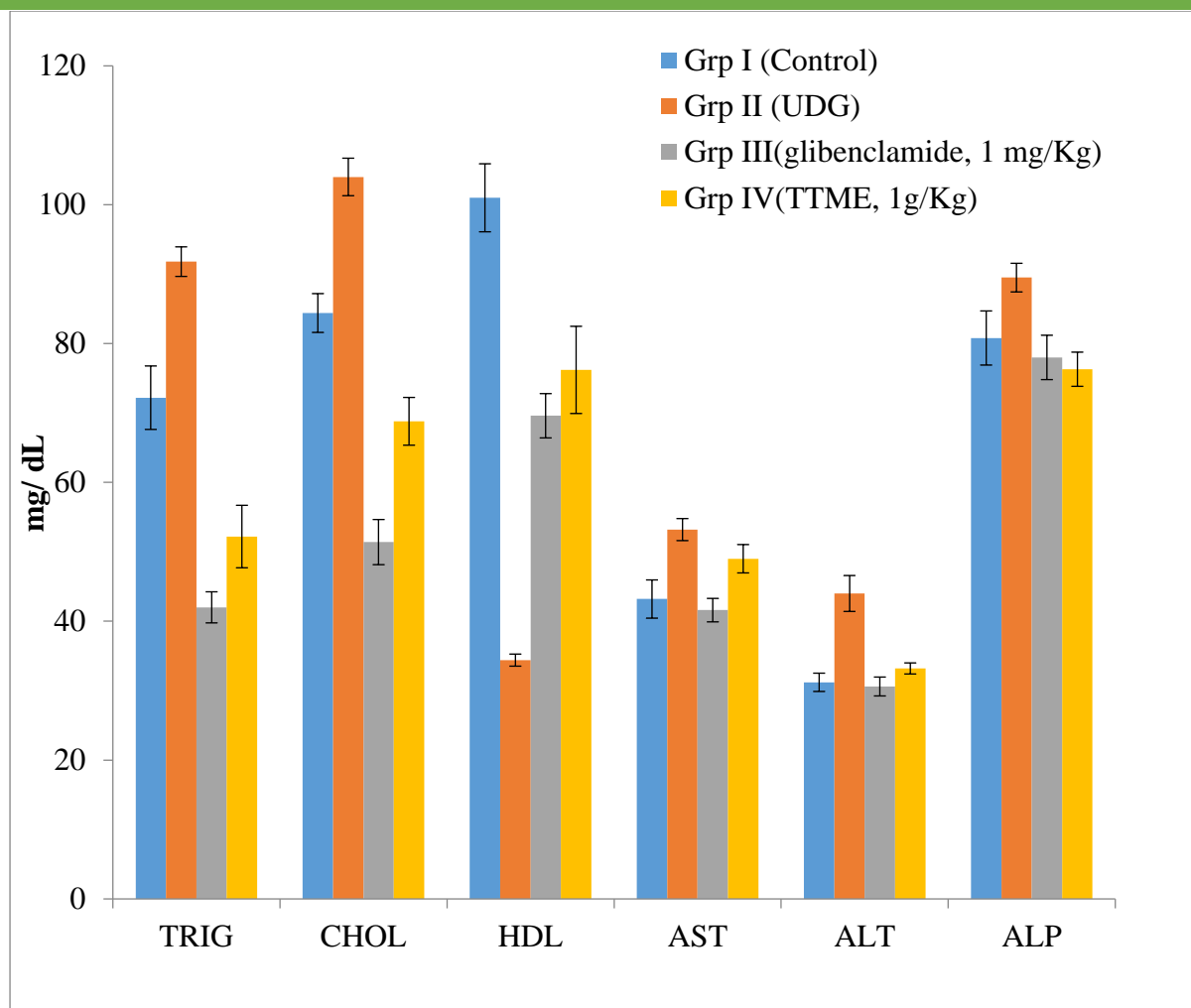


Figure 3: Result of biochemical analysis of the blood samples from experimental animals

Values expressed as mean \pm SEM; Means with the same superscript are not significantly different from each other ($p < 0.05$). UDG = untreated diabetic group and TTME = *T. tetraptera* fruit methanol extract, TRIG = total triglycerides, CHOL = total cholesterol, HDL = high density lipoprotein, AST = aspartate transferase, ALT = alkaline transferase and ALP = alkaline phosphatase.

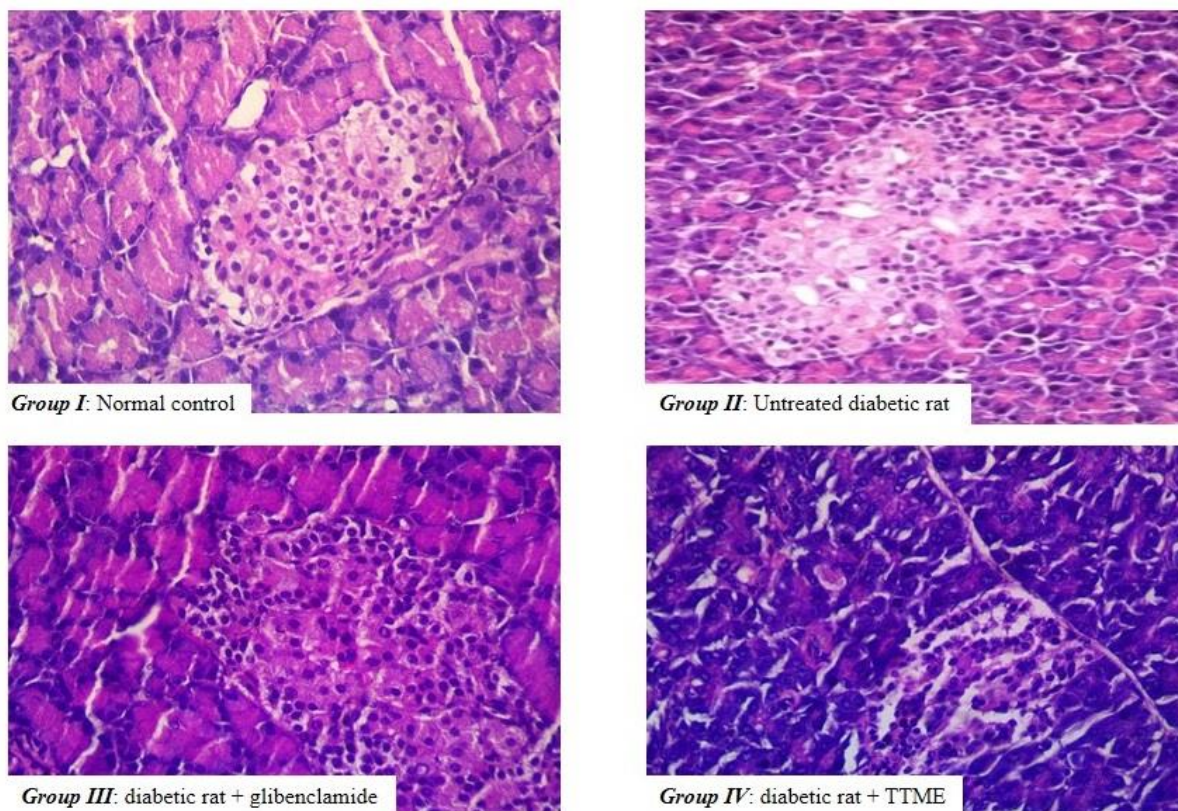


Figure 4: Histopathology of the pancreas of the experimental rats (X 400)