FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 10 No. 23, December, 2026, pp 350 – 358
DOI: https://doi.org/10.33003/fjs-2026-1023-6555

Effects of Aqueous *Kigelia africana* Fruit Extract on Glycaemic, Hepatic, Lipid, Haematological and Histopathological Indices in Streptozotocin-Induced Diabetic Rats

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Received: 02 Oct. 2026
Accepted: 17 Nov. 2026
Published: 17 Nov. 2026

ABSTRACT

Diabetes mellitus is a chronic metabolic disorder characterised by persistent hyperglycaemia and associated alterations in lipid metabolism, liver function, haematological indices and tissue integrity. This study investigated the effects of aqueous fruit extract of *Kigelia africana* on blood glucose levels, liver marker enzymes, lipid profile, selected haematological parameters, and histopathological changes in streptozotocin-induced diabetic Wistar albino rats. Five groups were used: Group A (normal control), Groups B and C (200 and 400 mg/kg body weight *K. africana* extract), Group D (metformin), and Group E (negative control). Diabetes was induced with streptozotocin. We assessed blood glucose, serum liver enzymes, lipid profile, and haematological parameters using standard methods; we also examined liver and kidney histopathology. Untreated diabetic rats showed marked hyperglycaemia, elevated liver enzymes, increased total cholesterol, triglycerides and LDL, reduced HDL, and decreased PCV, haemoglobin, WBC and RBC. *K. africana* extract significantly ameliorated these changes. Blood glucose fell from 218.0 ± 6.25 to 125.0 ± 5.36 mg/dL (200 mg/kg) and from 291.0 ± 4.50 to 132.0 ± 3.15 mg/dL (400 mg/kg). Liver enzymes and lipid parameters improved compared with untreated controls. Haematological indices improved, with the 400 mg/kg dose generally superior (except WBC). Extract-treated groups had better-preserved liver and kidney architecture than untreated diabetics. One-way ANOVA detected significant changes. Aqueous K. africana fruit extract showed hypoglycaemic, protective, hypolipidaemic, haematoprotective and tissue-protective effects in streptozotocin-induced diabetic rats and may serve as a complementary source of bioactive compounds for managing diabetes-associated complications, pending further studies on active constituents, mechanisms and safety.

Keywords: *Kigelia Africana*, Diabetes Mellitus, Hypolipidaemic. Streptozotocin, Hypoglycemic Effect, Nephropathy, Haematological Parameters, Wistar Rats

INTRODUCTION

Diabetes mellitus (DM) is a progressive metabolic disorder characterised by persistent hyperglycaemia, which drives multisystem complications, including hepatic dysfunction, diabetic dyslipidaemia, haematological disturbances and tissue injury. Global prevalence rose from ~200 million adults in 1990 to 830 million in 2022, with the steepest increases in low- and middle-income countries (WHO, 2017; NCD-RisC, 2024). In 2017, diabetes affected 451 million adults worldwide, projected to rise to 693 million by 2045 (WHO, 2017). The global burden of diabetes has increased considerably, particularly in low- and middle-income countries.

The liver plays a central role in glucose and lipid metabolism and is therefore particularly important in diabetes. Persistent hyperglycaemia, altered lipid metabolism and oxidative stress may contribute to hepatic dysfunction. Changes in liver-associated enzymes, particularly alanine aminotransferase (ALT), aspartate aminotransferase (AST) and alkaline phosphatase (ALP), can provide useful biochemical information about hepatocellular or hepatobiliary alterations. Consequently, assessing liver marker enzymes may help determine whether an intervention protects or adversely affects hepatic function in experimentally diabetic animals.

Typical diabetic dyslipidaemia is characterised by elevated triglycerides, reduced high-density lipoprotein cholesterol (HDL-C), and qualitative and quantitative abnormalities in low-density lipoprotein cholesterol (LDL-C). These abnormalities contribute substantially to the increased risk of atherosclerotic cardiovascular disease among individuals with diabetes (Schofield *et al*., 2016; Raizada *et al.,* 2024). With different breakthroughs in the development of drugs used in the treatment of diabetes, limitations are, however, the toxic side effects with derangements in biochemical, haematological, and histological parameters associated with the progression (Oyedemi *et al.*,2011), together with the generation of free radicals implicated in the pathophysiology of the disease (Okine *et al.*,2005).

Diabetes can also affect the haematological system. Chronic hyperglycaemia is associated with oxidative stress, inflammation and alterations in erythropoiesis and blood-cell function. Studies have reported alterations in red blood cell indices, white blood cell counts and platelet-related parameters among individuals with diabetes (Abdullah *et al.*, 2024). Thus, haematological parameters can provide additional information about the systemic effects of diabetes and the possible therapeutic or toxic effects of experimental treatments. (Abebe *et al.*, 2024).

Medicinal plants remain widely used, especially in resource-limited settings, because they are accessible, affordable, and perceived as safe. *Kigelia africana* (sausage tree) is traditionally used to manage diabetes and a range of inflammatory and dermatological conditions. Its large, woody fruits contain diverse secondary metabolites; studies have documented high antioxidant activity, particularly in non-polar fractions (Atawodi & Olowoniyi, 2014; Azu *et al.,* 2010; Fagbohun *et al.,* 2020). A comprehensive review confirms that multiple plant parts possess biologically active phytochemicals and several pharmacological activities (Nabatanzi *et al.,* 2020). Medicinal plants are used in several countries to manage different metabolic diseases and are thought to be cheaper than allopathic drugs. They are even available and affordable to many, especially in developing countries such as Nigeria (Okine *et al.,*2005). *Kigelia africana* is particularly relevant because of its extensive traditional medicinal applications and its documented phytochemical diversity. It is known as the sausage or cucumber tree (Atawodi, *et al.,* 2014) and is used traditionally in diabetes management. The plant is unique for its large, sausage-like fruits. It has an average weight of between 4 to 10 kg and hangs from a fibrous and long stalk (Azu *et al*.,2010). The fruit wall is woody, with distinctly marked lenticels on the surface, and it is an indehiscent fruit. It has grey-brown colouration with numerous seeds at maturation. The fruit is medicinal and employed in the treatment of several diseases and ailments such as tapeworm, ringworm, malaria, boils, eczema, psoriasis, malignant melanoma and solar keratosis (Atawodi *et al.,* 2014). An earlier study reported high antioxidant activity in fruit extracts, with the hexane fraction considered the most potent (Fagbohun *et al.,* 2020).

Despite ethnobotanical use and promising phytochemical data, experimental validation of K. africana aqueous fruit extract remains limited. Most published work has examined either different plant parts, non-aqueous fractions (e.g., hexane), or isolated antioxidant/enzyme-inhibitory activities in vitro. Consequently, researchers have not systematically evaluated the effects of aqueous fruit extract on the integrated suite of diabetes-associated endpoints, blood glucose, liver-marker enzymes, complete lipid profile, haematological indices, and concurrent liver/kidney histopathology, in a standardised streptozotocin (STZ) model. Therefore, many of the plant's traditional claims remain insufficiently supported by controlled in vivo evidence (Musinguzi *et al.,* 2020; Nabatanzi *et al.,* 2020). A comprehensive review by Musinguzi *et al.* (2020) noted that different parts of *K. africana* contain biologically active phytochemicals and possess several pharmacological activities, although many of the plant's traditional uses remain insufficiently validated experimentally. This study aims to evaluate the effects of aqueous *Kigelia africana* fruit extract on blood glucose, liver marker enzymes, lipid profile, haematological indices and tissue histology in streptozotocin-induced diabetic Wistar rats.

MATERIALS AND METHODS

Plant Collection and Preparation

The fruits of *K. africana* were purchased from Okene market in Okene local Government area, Kogi State, Nigeria. The fruits of *K. africana* were subjected to cutting, mincing, and subsequent air drying within a designated shed for a duration of one week. The desiccated pulverized fruits were subsequently pulverized and filtered using a screen with a hole diameter of 0.6 mm to acquire a uniform powder, which was afterwards stored at a temperature of 10°C

Processing and Extraction Procedure

A quantity of 500 grammes of powdered *Kigelia africana* fruit was extracted in a Soxhlet extraction process, employing 2500 milliliters of water as the extracting solvent, resulting in the production of an aqueous extract. (Emran *et al.,* 2015) The extracted substance was dried using a heating mantle until a solid or semi-solid mass was produced, and it was kept in desiccators. Before giving each extract to the animals orally, a weighed portion of each extract was dissolved in 1% gum acacia solution in filtered water. The oral feeding needle (cannula) was used to deliver the extracts orally. The dose chosen and the animal's weight was used to calculate the volume of extract delivered

Experimental Animals.

Male Wistar Strain albino rats of about six weeks old, weighing between 120- 150g obtained from the animal house of the Department of Pharmaceutical Science, ABU Zaria, were used for the experiment. The rats were kept and maintained in well ventilated cages under standard laboratory conditions and was maintained at ambient temperature and relative humidity respectively. Light and dark cycles were maintained at 12h each at the department of chemistry/ biochemistry. They were maintained on grower's mash (Vital feeds Nigeria Ltd) and provided with water *ad libitum.* They were allowed to acclimatize to the laboratory conditions for two weeks before the experiment.

Ethical Approval

Ethical approval was not obtained prior to the commencement of the study. However, all animal handling and experimental procedures were conducted in accordance with the relevant institutional and internationally accepted guidelines for the care and use of laboratory animals."

Experimental Design

A total of 25 male rats weighing between 120-150g were used for the study. The rats were divided into five groups of 5 rats each;

Group 1; Normal rats administered with feed and distilled water.

Group 2; Diabetic-induced rats administered with 200mg/kg b.w of the extract of *Kigelia Africana* fruit

Group 3; Diabetic-induced rats administered with 400mg/kg b.w of the extract of *Kigelia Africana* fruit

Group4: Diabetic-induced rats administered with an antidiabetic reference drug (metformin) of 250mg\kg b.w (positive control).

Group 5: Diabetic-induced rats administered without treatment (negative control).

After 21 days of administration, animals were humanely sacrificed and blood were collected for further analysis.

Induction of Experimental Diabetes

Diabetes mellitus was induced in 12 h-fasted rats by a single intraperitoneal injection of streptozotocin (55 mg/kg body weight) freshly dissolved in 0.1 M cold citrate buffer (pH 4.5), following the method of Burcelin*et al.* (1995). Blood glucose was assessed 72 h post-injection using a glucometer (Accu-Chek Advantage, Roche Diagnostics GmbH, Germany). We classified rats with fasting blood glucose concentrations exceeding 126 mg/dL (11.1 mmol/L) as diabetic and included them in the study.

Doses and Route of Administration of Extract

Animals with diabetes were post treated with *Kigelia africana* fruit extract. Extract was given in doses of 200 and 400 mg/kg orally with the help of a gavage.

Collection and Treatment of Samples
The sacrificing of the animals took place on the fourteenth days using cervical dislocation. Blood of each animal was collected into an EDTA tube and a plain tube via cardiac puncturing, left at room temperature for ½ of an hour, and centrifuged at 3000 rpm for 600 seconds to acquire a supernatant using a Pasteur pipette. The liver was also quickly eliminated, washed with normal saline, homogenized, and centrifuged at 4000 rpm for 900 seconds (Ajiboye *et al.*,2019).

Fasting Blood Glucose Determination
The fasting blood glucose level was determined by Clark and Lyons (1962) method using glucometer (Acc-check Advantage. Boche Diagnostic GmbH, Germany) after fasting the rats for 12h.

Determination of Liver Function Indices
The serum collected was used for analyzing liver function test (marker enzymes) such as Aspartate Transaminase (AST), and Alanine Transaminase (ALT) by the method described by Reitman and Frankel (1957) and Alkaline Phosphatase (ALP) by the method described by Tiets *et al* (1993) using test kits.

Lipid Profile
On Day 21, blood was collected by retro-orbital puncture under mild ether anesthesia from rats. The serum collected was used for analyzing lipid profile such as HDL cholesterol (Wacnic and Albers, 1978)., LDL cholesterol (Friedewald *et al.*,1972)., Triglyceride McGowan, *et al*., 1983) and Total cholesterol (Stein,1987) using test kits

Haematological Analysis
Haematological parameters such as white blood cell count (WBC), red blood cell count (RBC), packed cell volume (PCV) and platelet count was measured using a Beckman-Coulter AcT 5 Diff. haematology analyser according to manufacturer's guidelines (Beckman-Coulter UK Ltd). Differential white cell counts were performed manually based on a blood smear assessment of 200 leucocytes. (Ojediran *et al*., 2015)

Histopathological Examination
Paraffin wax method described by Bancroft and Gamble (2008) was used. Tissues were fixed in neutral buffered formalin for 72 hours. They were all processed using the automatic tissue processor (Leica). Tissues were dehydrated in ascending grades of alcohol for two hours each (70%, 90%, 95% and 100%). Tissues were transferred to xylene for cleaning. They were cleaned in two changes of xylene one hour each. Tissues were infiltrated with molten paraffin wax for two hours. Tissues were embedded in paraffin wax and later sectioned using routry microtone (Lieca) at 5 microns each. Tissues were floated out in water bath picked with glass slide and allowed to air dry for two hours, thereafter stained, with the routine Hematoxyline and Eosin (H and E) staining.

Hematoxylin and Eosin Staining Technigue (Bancroft and Gamble,2008)
Tissues were dewaxed in xylene solution and then dehydrated for one minute each, rinsed in water bath and stained with harris hematoxylin for 10 minutes. Tissues were briefly rinsed in water, then differentiated in 1% acidic alcohol. They were blued in scott´s tap water for 5 minutes. Tissues were counterstained in eosin for 2 minutes and then dehydrated in ascending grades of alcohol (70%,90%,100%) one minute each. tissues were cleaned in xylene solution in two minutes, then mounted in DPX and allowed to dry for 48 hours. Tissue was microscopically examined using x10 and x40 objective and photomicrograph using Amscope at 500 digital microscope

Statistical Analysis
Results were presented as mean ± SEM, ANOVA was carried out using the SPSS program (version 19 SPSS Inc, Chicago, USA) and the Duncan multiple range test was used to test the differences between groups. P value was set at 0.05 (Duncan *et al.*, 1955).

RESULTS AND DISCUSSION

Blood Glucose Level Determination
The results presented in Table 1 shows that streptozotocin-induced diabetes led to severe hyperglycemia in negative control (Group E), with blood glucose levels rising from 84.0 ± 8.43 to 325.0 ± 5.60 mg/dL over three weeks. The results reveal a consistent pattern in blood glucose reduction across the extract-treated groups. Group B (200 mg/kg) and Group C (400 mg/kg) showed significant decreases ($p<0.05$) in blood glucose levels from week 1 to week 3 post-induction, with Group B reducing from 218.0 ± 6.25 mg/dL to 125.0 ± 5.36 mg/dL and Group C from 291.0 ± 4.50 to 132.0 ± 3.15 mg/dL.

Keys
Group A = Normal control
Group B = Treated with 200mg/kg extract
Group C = Treated with 400mg/kg extract
Group D = Standard drug
Group E = Negative control

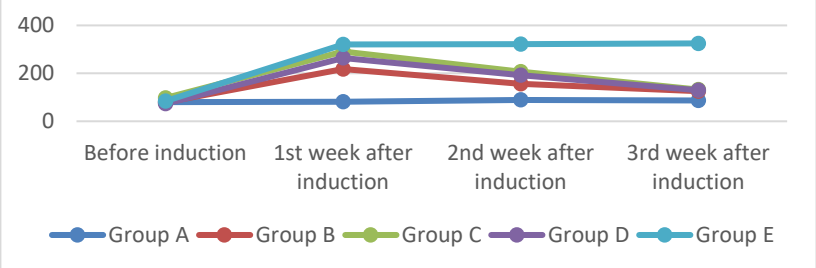


Figure 1: Shows The Hypoglycemic Effect of *K. Africana* L Fruit Extracts On Blood Glucose Level of Streptozotocin Induced Diabetic Rats

Attenuation of Liver Enzymes Activities
Hepatic enzyme markers provided further insight. Elevated AST, ALT, and ALP levels in Group E rats reflect hepatic

damage induced by chronic hyperglycemia. Group B rats, however, had near-normal enzyme values (AST: 21.4 ± 2.10 IU/L, ALT: 16.0 ± 0.51 IU/L, ALP: 192.0 ± 12.05 IU/L), indicating liver protection. The high dose group (C) and standard drug group (D) had slightly elevated ($p<0.05$) levels, but still markedly lower than the untreated control, reinforcing the therapeutic effect of the extract.

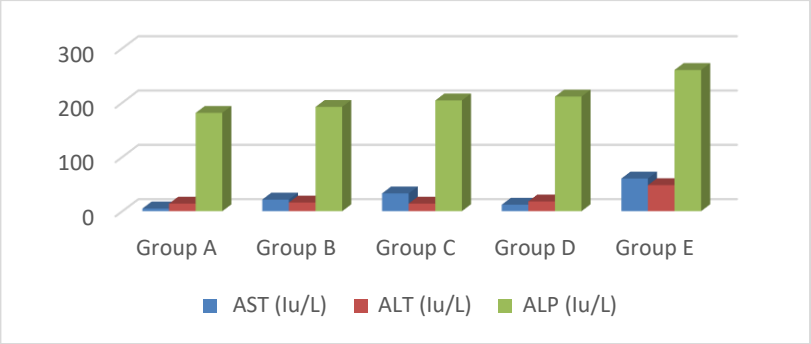


Figure 2: Shows Results for Liver Enzymes Activity (ALT, AST and ALP)

Hypolipidemic Effect of *Kigalia african* Fruit Extract

The lipid profile (Table 1) shows that *K. africana* fruit extracts led to marked improvements in dyslipidemia commonly associated with diabetes. Groups B and C showed significant reduction ($p<0.05$) in TC (3.30 ± 1.12 and 3.50 ± 1.01 mg/dL respectively) and TG levels, along with elevated HDL and reduced LDL, compared to the untreated group (Group E), which had the highest TC (5.10 ± 0.43 mg/dL) and lowest HDL (0.50 ± 0.01 mg/dL).

The Results in the Table 1 Below Shows Hypolipidemic Effect of *Kigalia african* Fruits Extracts on Blood Glucose level of Streptozotocin Induced Diabetic Rats.

Result= mean value ± SD of duplicate determinations. Different superscript in a column means that the difference is significant at probability value p = 0.05 (95% confidence interval), otherwise, there is no significant difference.

Hematological Modulation of Aqueous Fruit Extract of (*Kigelia africana*)

The untreated diabetic rats (Group E) showed significant reductions ($P<0.05$) in PCV (23.0%), Hb (9.0 g/dL), WBC (3.0×10^9/L), and RBC (3.2×10^6/µL), Conversely, rats in Group A (normal control) exhibited significantly higher hematological values, indicative of normal physiological balance. There was substantial improvement ($P<0.05$) in Group B (200 mg/kg ext.) in hematological parameters (PCV of 31.0%, Hb of 14.0 g/dL, WBC of 8.0×10^9/L, and RBC of 4.2×10^6/µL) when compared with the untreated group. Group C (400 mg/kg) showed significant improvements in all measured parameters when compared with the untreated group. The metformin-treated group (Group D) also exhibited improved hematological parameters (PCV: 38.0%, Hb: 15.0 g/dL, WBC: 6.40×10^9/L, RBC: 5.8×10^6/µL), validating its known efficacy in glycemic and hematologic restoration. Interestingly, the 400 mg/kg dose of *K. africana* appeared more effective than the 200 mg/kg dose except for WBC with (6.50×10^9/L)

Table 2: Shows Results on Effect of Aqueous Fruit Extract *of K. africana* Some Hematological Parameters (PCV, RBC, Platelets, WBC) in Streptozotocin Diabetics Induced Rats.

Treatment groups	PCV (%)	Hb(g/dl)	WBC ($x10^9$/l)	RBC ($x10^6$/l)
Group A	42.0 ± 2.51^e	16.0 ± 1.36^d	10.30 ± 2.23^d	6.70 ± 1.22^d
Group B	31.0 ± 3.22^b	14.0 ± 2.98^b	8.36 ± 1.33^c	4.20 ± 1.42^b
Group C	34.0 ± 1.26^c	15.5 ± 1.77^c	6.50 ± 1.38^b	5.00 ± 1.24^b
Group D	38.0 ± 2.22^d	15.0 ± 2.22^c	8.40 ± 1.16^b	5.80 ± 2.51^c
Group E	23.0 ± 3.15^a	9.0 ± 2.30^a	3.70 ± 0.36^a	3.00 ± 1.89^a

Results are expressed as mean value ± SD. Different superscript in a column means that the difference is significant at probability value p<0.05 (95% confidence level

Photomicrograph of Kidney of Diabetic Induced Wistar Rats Treated with Extract of *Kigelia Africana* Fruits

Histological section of the kidney tissues shows normocellular glomerular tufts displayed on a background containing renal tubules. No abnormalities were seen in group A to D. But there was abnormalities observed in group E, histologic sections of kidney tissue of normal control (Group A) show *normocellular glomerular* tufts disposed on a background containing viable tubules when compared with the negative control group **(**Group E), Histological section of the kidney also show normocellular glomerular tufts disposed on a background containing viable tubules in all the diabetic experimental groups i.e (DE+ 200mg/dl and DE + 400mg/dl and STD drug).

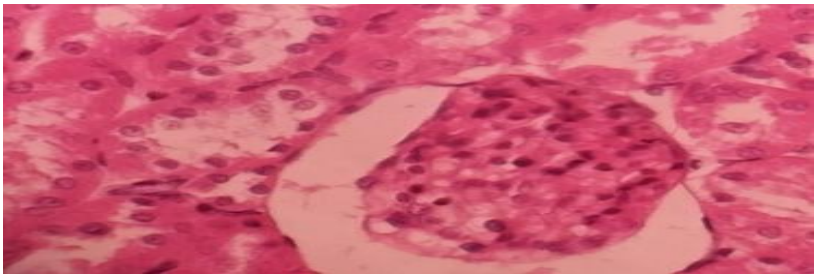


Plate A: Group A Kidney



Plate B: Group B Kidney

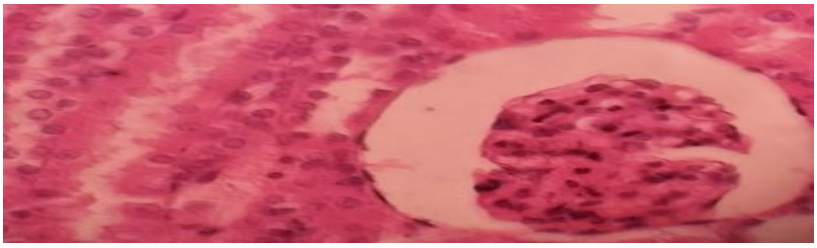


Plate C: Group C Kidney

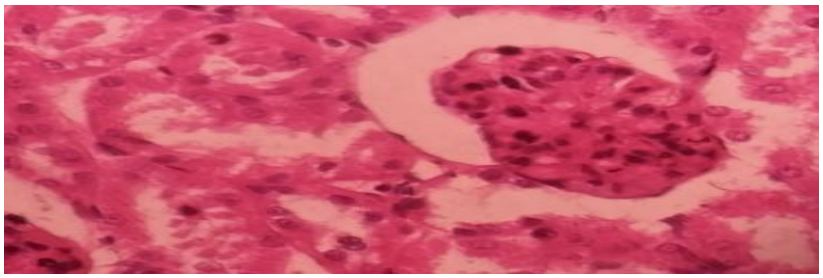


Plate D: Group D kidney

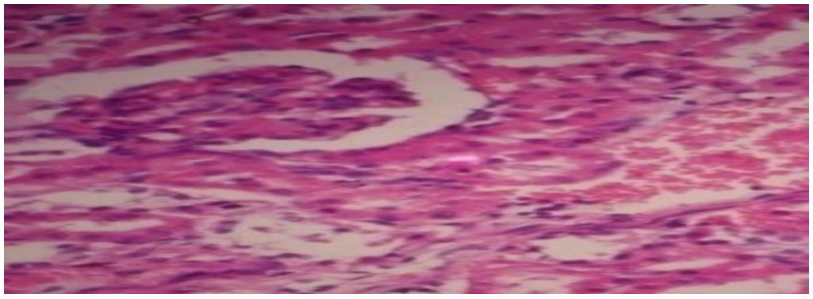


Plate E: Group E kidney

Figure 3: Photomicrographs of Sections of Rats' Kidney (H & E stain x250), showing A = Normal Control, B & C= Diabetic Experimental Group Treated with 200mg/dl and400mg/dl *K. Africana* fruit Extract Respectively, 4 = D and E = Diabetic Experimental Group Treated with a Standard Drug (Metformin) and Negative Control

Photomicrograph of Liver of Diabetic Induced Wistar Rats Treated with Extract of *Kigelia Africana* Fruits

Histological section of the liver tissues shows parallel plates of hepatocytes radiating away from central veins. No abnormalities were seen in group A to D. But the diabetic control group without treatment (group E) shows, significant liver damage including inflammation, hepatocytes necrosis, fatty degeneration and inflammatory cell infiltration.

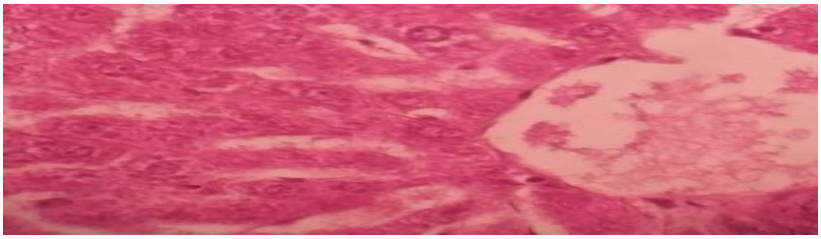


Plate A: Group A liver

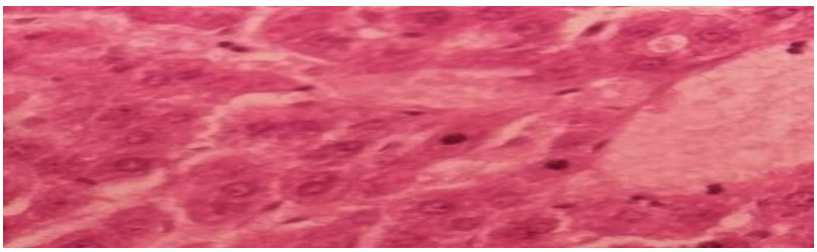


Plate B: Group B liver

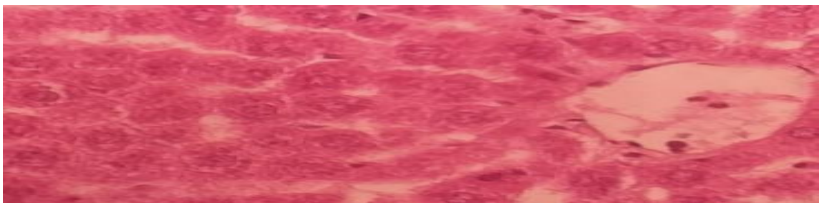


Plate C: Group C liver

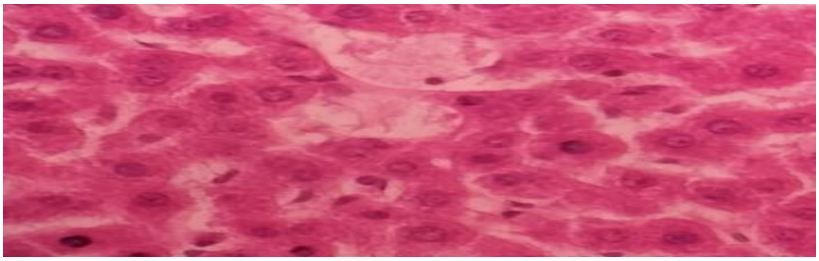


Plate D: Group liver

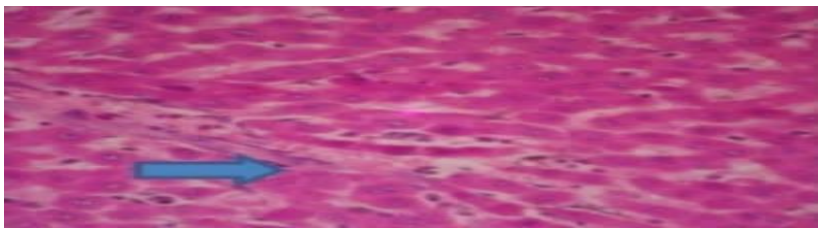


Plate E: Group E liver

Figure 4: Photomicrographs of Sections of Rats' Liver (H & E stain x250), Showing A = Normal Control, B & C= Diabetic Experimental Group Treated with 200mg/dl and400mg/dl *K. Africana* Fruit Extract Respectively, 4 = D and E = Diabetic Experimental Group Treated with a Standard Drug (Metformin) and Negative Control

Discussion

The results of this study demonstrated that streptozotocin (STZ) induction produced a marked increase in blood glucose concentration in the untreated diabetic rats (Group E), reaching 325.0 ± 5.60 mg/dL by the third week. Treatment with *Kigelia africana* fruit extract produced a substantial reduction in blood glucose concentration. The 200 mg/kg treated group decreased from 218.0 ± 6.25 mg/dL to 125.0 ± 5.36 mg/dL, while the 400 mg/kg group decreased from 291.0 ± 4.50 mg/dL to 132.0 ± 3.15 mg/dL by the third week. The reduction in blood glucose suggests that the fruit extract possesses antihyperglycaemic activity.

The finding is supported by Muyenga *et al.* (2024), who demonstrated that fractions of *K. africana* fruit inhibited α-glucosidase activity in vitro. α-Glucosidase is involved in the digestion of carbohydrates into absorbable glucose; therefore, inhibition of this enzyme can potentially reduce postprandial glucose release and contribute to glycaemic control. Nabatanzi *et al.* (2020) reported that *K. africana* contains several classes of bioactive compounds, including phenolic compounds and flavonoids, and reviewed evidence for antioxidant and other pharmacological activities of the plant.Fagbohun *et al.* (2020) is particularly supportive of the general finding, although their experimental preparation was

a hexane fraction rather than the aqueous extract used in the present study. The effect was not perfectly dose-dependent in the present study because the 200 mg/kg group recorded a slightly lower final glucose concentration than the 400 mg/kg group.

The liver enzyme results demonstrated alterations in AST, ALT and ALP in the untreated diabetic animals, suggesting hepatic injury associated with experimental diabetes. In the present study, treatment with *K. africana* fruit extract resulted in lower enzyme activities compared with the untreated diabetic group. Group B recorded AST of 21.4 ± 2.10 IU/L, ALT of 16.0 ± 0.51 IU/L and ALP of 192.0 ± 12.05 IU/L. The reduction in these enzyme activities suggests attenuation of diabetes-associated hepatic injury.The possible hepatoprotective effect of *K. africana* may be related to its antioxidant phytochemicals. Nabatanzi *et al.* (2020) reviewed several studies demonstrating antioxidant activity in different parts of *K. africana*, including the fruit. The authors also reported the presence of phenolic compounds, flavonoids and other secondary metabolites that may contribute to the plant's biological activities. Fagbohun *et al.* (2020), using a different *K. africana* fruit fraction, also reported amelioration of biochemical and histopathological abnormalities in STZ-induced diabetic rats.

The untreated diabetic rats showed marked dyslipidaemia, characterized by elevated total cholesterol, triglycerides and LDL together with reduced HDL. Group E recorded total cholesterol of 5.10 ± 0.43 mmol/dL, triglycerides of 2.30 ± 0.02 mmol/dL, LDL of 3.00 ± 0.32 mmol/dL and HDL of 0.50 ± 0.01 mmol/dL. These findings are consistent with previous experimental studies showing that STZ-induced diabetes can produce significant disturbances in lipid metabolism. Jafarnejad *et al.* (2008), for example, reported increased triglycerides, total cholesterol and LDL cholesterol and decreased HDL cholesterol in STZ-induced diabetic rats compared with negative controls. The development of dyslipidaemia in diabetes is associated with impaired insulin action and altered lipid metabolism. Administration of *K. africana* fruit extract improved several lipid parameters in the present study. Total cholesterol decreased to 3.30 ± 1.12 mmol/dL in Group B and 3.50 ± 1.01 mmol/dL in Group C. Triglycerides also decreased compared with the untreated diabetic group, while LDL was reduced to 1.30 ± 0.41 and 1.30 ± 0.52 mmol/dL in Groups B and C, respectively. These results suggest that *K. africana* fruit extract possesses lipid-modulating activity. Independent evidence from Fagbohun *et al.* (2020) showed that *K. africana* fruit fractions reduced hyperlipidaemic biomarkers in STZ-induced diabetic rats. The antioxidant properties of *K. africana* may also contribute to the observed lipid-modulating effect. Fagbohun *et al.* (2020) reported antioxidant activity in *K. africana* fruit extracts, while Nabatanzi *et al.* (2020) reviewed evidence that the plant contains phenolic and flavonoid compounds associated with antioxidant activity. Although HDL increased in the treated diabetic groups compared with the untreated diabetic group. This suggests that the extract may reduce cardiovascular risk in diabetic patients by improving lipid metabolism, likely through inhibition of cholesterol biosynthesis or promotion of lipid catabolism (Iwu *et al.*, 2000; Ojewole, 2005).

The untreated diabetic rats exhibited considerable reductions in PCV, haemoglobin, WBC and RBC compared with the normal control. Group E recorded PCV of 23.0%, haemoglobin of 9.0 g/dL, WBC of 3.70 × 10^9/L and RBC of 3.00 × 10^6/µL.The reduction in erythrocyte-related parameters may indicate impairment of normal haematological function during diabetes. Chronic hyperglycaemia may promote oxidative stress and metabolic disturbances that affect erythrocyte survival and erythropoiesis. Treatment with *K. africana* fruit extract improved the haematological profile. At 200 mg/kg, PCV increased to 31.0%, haemoglobin to 14.0 g/dL, WBC to 8.36 × 10^9/L and RBC to 4.20 × 10^6/µL. At 400 mg/kg, PCV increased to 34.0%, haemoglobin to 15.5 g/dL and RBC to 5.00 × 10^6/µL.

The improvement suggests that the extract may attenuate diabetes-associated haematological disturbances. This could be related to improved glucose regulation and antioxidant protection. The presence of antioxidant phytochemicals in *K. africana* has been documented by several investigators. Fagbohun *et al.* (2020) reported antioxidant activity in fruit extracts, while Nabatanzi *et al.* (2020) reviewed evidence for antioxidant activity and the presence of phenolic and flavonoid compounds in the plant.The improvement in haematological indices is also supported by research on other medicinal plants investigated in STZ-induced diabetes. Oyedemi *et al.* (2011). reported that treatment with aqueous *Afzelia africana* stem-bark extract produced antidiabetic and beneficial haematological effects in STZ-induced diabetic Wistar rats. Interestingly, the present study did not demonstrate a completely uniform dose-response relationship. The 400 mg/kg dose produced higher PCV, haemoglobin and RBC values than the 200 mg/kg dose, but the WBC value was lower. This suggests that the effect of the extract may differ according to the particular haematological parameter being measured.

Histological examination revealed relatively preserved renal architecture in the normal control and treated groups (group E), whereas abnormalities were observed in the untreated diabetic group (group E). The normal control showed normocellular glomerular tufts and viable renal tubules, while the untreated diabetic group showed pathological alterations.The renal changes observed in the diabetic animals may be associated with prolonged hyperglycaemia, oxidative stress and diabetes-related tissue injury. This supports previous findings that chronic hyperglycemia leads to oxidative stress and renal structural damage (Giacco and Brownlee, 2010). In the present study, the relatively normal renal architecture observed in the extract-treated groups (groups B,200 mg/kg and C, 400 mg/kg), suggests a possible protective effect of *K. africana* fruit extract against diabetes-associated renal injury. This could be attributed to the presence of phytochemicals like flavonoids, phenols, and saponins in *Phoenix dactylifera*, which have documented antioxidant and anti-inflammatory effects (Al-Qarawi *et al.*, 2004; Vayalil, 2012). Reducing oxidative stress may therefore help preserve renal cellular structures.

The liver plays a central role in glucose and lipid metabolism and is highly susceptible to diabetic complications. Group A (control) liver sections showed intact hepatocyte architecture with hepatocyte plates radiating from central veins—a typical feature of normal liver tissue. Similarly, groups B and C showed no significant morphological deviations, suggesting the extract preserved hepatic structure even in diabetic states. Group D also showed similar protection, validating Metformin's known hepatoprotective properties. In stark contrast, group E showed significant liver damage, characterized by fatty liver degeneration (steatosis), hepatocellular necrosis, and infiltration by inflammatory cells. Rodrigues *et al.* reported hepatic damage and changes in liver phospholipid composition following prolonged STZ-induced hyperglycaemia in Wistar rats.The absence of obvious major abnormalities in Groups B and C indicates that administration of *K. africana* fruit extract was associated with

preservation of hepatic architecture. This finding agrees with the reduction in liver enzyme activities observed in the biochemical results.

The possible protective effect may be related to the antioxidant properties of *K. africana*. Hussain and colleagues, as summarized by Nabatanzi *et al.*,2020 reported antioxidant activity for *K. africana* fruit extracts, while other phytochemical investigations have identified phenolic compounds and flavonoids in the plant. Therefore, the agreement between the biochemical liver-enzyme results and the histological observations provides stronger evidence that *K. africana* fruit extract may attenuate diabetes-associated hepatic injury.

CONCLUSION

The present study has shown that streptozotocin-induced diabetes produced marked biochemical, haematological and histological alterations in Wistar rats. The untreated diabetic animals showed severe hyperglycaemia, an adverse lipid profile, alterations in liver enzyme activities, reductions in selected haematological parameters and pathological changes in the liver and kidney.Administration of aqueous *Kigelia africana* fruit extract at 200 and 400 mg/kg produced considerable improvement in these diabetes-associated abnormalities. The extract reduced blood glucose concentration and improved total cholesterol, triglycerides and LDL compared with the untreated diabetic group. It also improved PCV, haemoglobin, RBC and WBC values and was associated with relatively preserved hepatic and renal tissue architecture.

The findings therefore indicate that aqueous *Kigelia africana* fruit extract possesses promising antihyperglycaemic, lipid modulating, haematopr otective and hepatoprotective/possible nephroprotective effects in STZ-induced diabetic Wistar rats.The observed effects may be associated with the phytochemical and antioxidant properties of *K. africana*, as well as possible effects on carbohydrate digestion and metabolism.

RECOMMENDATION

Further studies should be conducted to isolate and identify the specific phytochemical constituents of *Kigelia africana* fruit responsible for its antihyperglycaemic, lipid-modulating and organ-protective effects. A wider range of doses should be investigated to establish the optimum therapeutic dose and determine whether the response is truly dose-dependent. Future studies should investigate oxidative-stress biomarkers such as malondialdehyde (MDA), superoxide dismutase (SOD), catalase (CAT) and reduced glutathione (GSH) to establish whether antioxidant activity contributes to the observed protective effects. Pancreatic histology and serum insulin should be assessed in future experiments to determine whether the reduction in blood glucose is associated with preservation or regeneration of pancreatic β-cells. Additional renal-function tests, including serum urea, creatinine, electrolytes and urinary albumin, should be performed alongside kidney histology to provide stronger evidence of nephroprotection. Further studies should evaluate other liver-function indicators, including bilirubin, albumin and total protein, to provide a more comprehensive assessment of hepatic function.

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