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Ameliorative Effects of Methanol Leaf Extract of *Justicia carnea* on Streptozotocin-Induced Diabetic Organopathy in Wistar Rats: A Histopathological Assessment

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ABSTRACT: Diabetes mellitus is a chronic metabolic disorder marked by persistent hyperglycemia, which progressively impairs multiple organ systems. This study evaluated the histopathological effects of streptozotocin (STZ)-induced diabetes on the pancreas, liver, and kidneys of Wistar rats, and also assessed the protective potential of the methanol leaf extract of *Justicia carnea*. Thirty-six male Wistar rats were assigned to six groups (n = 6). Group 1 served as the normal control, while diabetes was induced in the remaining groups with STZ (50 mg/kg). Group 2 remained untreated, Group 3 received metformin (50 mg/kg), and Groups 4 – 6 were administered 100, 200, and 500 mg/kg of *J. carnea* extract, respectively, for 28 days. Untreated diabetic rats showed severe hepatic lesions, including marked vascular congestion and periportal inflammation, whereas the extract-treated groups exhibited progressive restoration of normal hepatic architecture, most notably at 200 and 500 mg/kg. Renal tissues from untreated diabetics displayed glomerular shrinkage, tubular necrosis, and interstitial congestion; these abnormalities were substantially reversed by *J. carnea*, with the highest dose producing histology comparable to that of normal and metformin-treated rats. Pancreatic sections from diabetic controls revealed pronounced islet degeneration and vascular congestion, while extract treatment resulted in dose-dependent improvement, including islet regeneration and reduced inflammation. Overall, *Justicia carnea* methanol leaf extract demonstrated significant protective and restorative effects on pancreatic, hepatic, and renal tissues in STZ-induced diabetic rats. These results support its potential as a promising phytotherapeutic agent for mitigating diabetes-related organ damage and as a possible adjunct to conventional therapies.

Keywords: Ameliorative effects, Diabetes mellitus, *Justicia carnea*, Histopathology, Streptozotocin,

Introduction

Diabetes mellitus (DM) comprises a group of metabolic disorders characterised by chronic hyperglycemia resulting from impaired insulin secretion, insulin action, or both (American Diabetes Association (ADA), 2014). Reduced insulin activity disrupts carbohydrate, lipid, and protein metabolism, leading to diverse systemic complications (Craig *et al*.,2009; Fayez *et* al., 2023). Clinically, DM presents with polyuria, polydipsia, polyphagia, unexplained weight loss, blurred vision, and, in severe, untreated cases, ketoacidosis, stupor, coma, or death (Fayez *et* al., 2023). The two primary forms of diabetes are type 1 diabetes mellitus (T1DM), an autoimmune destruction of pancreatic β-cells that necessitates lifelong insulin therapy, and type 2 diabetes mellitus (T2DM), which is characterised by insulin resistance with relative insulin deficiency and is strongly associated with obesity, physical inactivity, and genetic predisposition (ADA, 2021).

Uncontrolled DM exerts profound multisystem effects. Cardiovascular disease, stroke, and peripheral arterial disease remain the most common causes of diabetes-related morbidity and mortality (Smith and Jane, 2020). Chronic hyperglycemia contributes to microvascular complications such as diabetic nephropathy, retinopathy, and neuropathy (Reed *et al*., 2021). In the kidneys, persistent hyperglycemia induces glomerular hyperfiltration,

mesangial expansion, basement membrane thickening, and tubulointerstitial fibrosis, ultimately progressing to renal failure (Reed *et al*., 2021). In the liver, insulin resistance promotes *de novo* lipogenesis, hepatic steatosis, and inflammation, facilitating the transition from non-alcoholic fatty liver disease (NAFLD) to non-alcoholic steatohepatitis (NASH), cirrhosis, and hepatocellular carcinoma (Levinthal and Tavill, 1999; Mohamed *et al*., 2016). Pancreatic β-cell loss and islet degeneration further exacerbate hyperglycemia, particularly in experimentally induced diabetes (Sharan, 2019).

Streptozotocin (STZ), a nitrosourea derivative (2-deoxy-2-(3-methyl-3-nitrosoureido)-D-glucopyranose), is a naturally occurring alkylating agent that selectively targets pancreatic β-cells via glucose transporter-2 (GLUT2) (Eleazu *et al*., 2013; Furman, 2021). A single intraperitoneal dose of STZ (typically 50 – 60 mg/kg) consistently induces a T1DM-like state in rodents, characterised by marked hyperglycemia, hypoinsulinemia, and histologically evident β-cell necrosis (Furman, 2021).

Medicinal plants have long been central to traditional healthcare, with an estimated 80 % of the global population relying on plant-based remedies (WHO, 2005). Africa alone hosts thousands of ethnomedicinal species with reported antioxidant, anti-inflammatory, antidiabetic, hepatoprotective, and nephroprotective properties (Ayoka *et al*., 2006; Ahirwar, 2023). *Justicia carnea* (family Acanthaceae), commonly known as "blood booster" or "Ogwu Obara" in southeastern Nigeria, is an ornamental and medicinal shrub widely cultivated across tropical Africa (Sofowora, 1996). Traditionally, it is used for managing anaemia, diabetes, diarrhoea, arthritis, liver disorders, and inflammatory conditions (Badami *et al*., 2003; Correa, 2012; Onyeabo *et al*., 2017). Pharmacological studies further support its antidiabetic, antioxidant, hypolipidemic, antiviral, and cardioprotective potentials (Abo *et al*., 2008; Medapa *et al*., 2011; Orjiakor *et al*., 2019). Although several studies have demonstrated the hypoglycemic effects of *J. carnea* leaf extracts in diabetic animal models (Ukpabi-Ugo *et al*., 2018; Ukpabi-Ugo *et al*., 2023; Ojeaburu and Olasehinde, 2024), comprehensive histopathological evaluation of its protective effects on the pancreas, liver, and kidneys in STZ-induced diabetes remains limited.

The present study was therefore designed to investigate the ameliorative effects of graded doses of *J. carnea* methanol leaf extract on the histomorphology of the pancreas, liver, and kidneys in streptozotocin-induced diabetic Wistar rats, with metformin serving as the standard reference drug.

Materials and methods

Chemicals and reagents: All chemicals and reagents were of analytical grade and were procured from British Drug House (BDH, England) and Sigma-Aldrich (St. Louis, MO, USA).

Plant material and extract preparation: Fresh leaves of *Justicia carnea* were collected from Ovbiogie community, Ovia North-East Local Government Area, Edo State, Nigeria. Authentication was performed at the Department of Plant Biology and Biotechnology, University of Benin, Benin City, Nigeria, and a voucher specimen (UBH-J386) was deposited in the departmental herbarium.

The leaves were washed with distilled water, air-dried at ambient temperature, and pulverised using a mechanical grinder. Five hundred grams (500 g) of the powdered material was macerated in 5 L of absolute methanol for 72 h with intermittent agitation. The mixture was filtered through muslin cloth, and the filtrate was concentrated under reduced pressure using a rotary evaporator at 60 °C, followed by lyophilisation. The resulting methanol leaf extract of *Justicia carnea* (MEJC) was stored at −4 °C until required for experimentation.

Experimental animals: Thirty-six (36) healthy adult male Wistar rats (8 weeks old; 180 – 200 g) were obtained from the Animal Holding Unit, Department of Biochemistry, University of Benin. Animals were housed in stainless-steel cages under standard laboratory conditions (temperature 24 ± 2 °C, relative humidity 55– 65 %, 12-h light/dark cycle) and provided unrestricted access to standard pellet feed and clean water. A 14-day acclimatisation period preceded the experiment. All experimental procedures conformed to the National Research Council (US) Institute for Laboratory Animal Research (Guide for the Care and Use of Laboratory Animals, Washington (DC):1996) and were approved by the Research Ethics Committee of the Faculty of Life Sciences, University of Benin, Benin City, Nigeria (Approval reference: FLSRE-2023-018).

Acute oral toxicity study: Acute oral toxicity of JCME was assessed following Lorke's 1983 method. In phase I, nine rats were distributed into three groups (n = 3) and administered single oral doses of 10, 100, or 1000 mg/kg body weight. Animals were monitored for behavioural changes, signs of toxicity, and mortality at 1 h post-administration and periodically for 24 h. Since no mortality occurred, phase II was conducted using three rats dosed at 1600, 2900, and 5000 mg/kg. Observation continued for 72 h. The Lethal Dose, 50% (LD_{50}) was estimated from the combined phases.

Induction of diabetes: Diabetes was induced by a single intraperitoneal injection of streptozotocin (STZ; Sigma-Aldrich, USA) at 50 mg/kg body weight, dissolved in freshly prepared 0.1 M cold citrate buffer (pH 4.5), following an overnight fast. Seventy-two hours post-induction, fasting blood glucose (FBG) was determined using an Accu-Chek Active glucometer (Roche Diagnostics, Germany). Rats with FBG ≥ 200 mg/dL were classified as diabetic and included in the study.
Experimental design and treatment: The animals were assigned to six groups of six rats each (n = 6):
Group 1: Normal control (distilled water, 5 mL/kg)
Group 2: Diabetic control (untreated)
Group 3: Diabetic + Metformin (50 mg/kg)
Group 4: Diabetic + JCME (100 mg/kg)
Group 5: Diabetic + JCME (200 mg/kg)
Group 6: Diabetic + JCME (500 mg/kg)
All treatments were administered orally once daily for 28 consecutive days. Body weight and fasting blood glucose were recorded weekly.
Sacrifice and organ collection: At the end of the treatment period, animals were fasted overnight and euthanised under light diethyl ether anaesthesia. The pancreas, liver, and kidneys were excised, rinsed in ice-cold normal saline, blotted dry, and fixed immediately in 10 % neutral buffered formalin for histological assessment.
Histopathological examination: Fixed tissues were processed by standard histological procedures: dehydration in ascending grades of ethanol, clearing in xylene, and embedding in paraffin wax. Thin sections (4 – 5 µm) were cut using a rotary microtome and stained with hematoxylin and eosin (H&E). Slides were examined under a light microscope (Olympus BX-51) at ×100 and ×400 magnifications, and photomicrographs were captured with a digital imaging system.
For quantitative renal assessment, 25 circular proximal tubules were selected per microscopic field, and diameters were measured along two perpendicular axes using Image-Pro Plus software (version 3.0, Media Cybernetics, USA).
Statistical analysis: Data were expressed as mean ± standard error of the mean (SEM). Statistical comparisons were performed using one-way analysis of variance (ANOVA) followed by Duncan's multiple range test in SPSS software (version 20.0; IBM Corp., Armonk, NY, USA). Differences were considered statistically significant at $p < 0.05$.

Results

Acute toxicity test: No signs or symptoms of toxicity were observed in any of the rats administered the methanol extract of *Justicia carnea* up to the highest tested dose of 5000 mg/kg body weight. The extract produced no mortality in both phases of the acute toxicity study (Tables 1 and 2).
In addition, the animals showed no drug-related alterations in behaviour, respiratory pattern, skin condition, water intake, food consumption, or body temperature. On this basis, the extract was considered safe at 5000 mg/kg, and the median lethal dose (LD_{50}) was estimated to exceed 5000 mg/kg.

Table 1: Phase 1 Acute toxicity test

Dose (mg/kg bw of MEJC)	Mortality
10	0/3
100	0/3
1000	0/3

Table 2: Phase 2 Acute toxicity test

Dose (mg/kg bw of MEJC)	Mortality
1500	0/3
2500	0/3
5000	0/3

Effect of J. carnea on blood glucose concentration of Streptozotocin-induced diabetic rats: Graded doses of *J. carnea* methanol leaf extract significantly reduced fasting blood glucose levels in STZ-induced diabetic rats ($p < 0.05$), with the 500 mg/kg dose producing the most pronounced effect (Table 3).

Table 3: Blood glucose concentration (mg/dL) of diabetic rats

Group	Initial	Week 1	Week 2	Week 3	Week 4
Group 1 (Control)	76.00±4.15	—	103.67±2.53^{b}	92.33±2.37^{b}	65.50±3.42^{b}
Group 2 (Diabetic Control)	94.67±14.45	305.00±27.40^{a}	475.00±41.02^{a}	368.00±54.08^{a}	369.33±28.01^{ab}
Group 3 (Metformin)	62.20± 3.88	310.80±56.81^{a}	286.40±55.00^{ab}	204.60±51.17^{ab}	168.00±76.00^{ab}
Group 4 (100 mg/kg)	58.80± 4.11	283.20±50.71^{a}	223.00±58.15^{ab}	222.00±59.05^{ab}	171.20±67.12^{ab}
Group 5 (200 mg/kg)	56.80± 1.65	370.20±49.42^{a}	321.75±53.10^{ab}	295.00±52.16^{ab}	222.33±62.22^{ab}
Group 6 (500 mg/kg)	59.17± 6.32	297.67±43.31^{a}	240.20±70.83^{ab}	190.00± .08^{ab}	53.00 ± 12.00^{b}

Values are mean ± SEM (n = 6). Superscript a: significantly different from the normal control ($p < 0.05$). Superscript b: significantly different from the diabetic control ($p < 0.05$). Superscript ab: significantly different from both controls but not significantly different from the metformin group.

Effect of J. carnea methanol extract on body weight: Table 4 shows the body-weight changes of diabetic rats treated with *J. carnea* extract. All groups exhibited weight gain over the 28 days. Groups 4 and 5 (100 and 200 mg/kg) recorded significantly lower weight gain than both the normal and diabetic control groups ($p < 0.05$).

Table 4: Changes in body weight of diabetic rats treated with *J. carnea* extract

Group	Initial Body Weight (g)	Final Body Weight (g)	Change in Body Weight (g)
Group 1 (Control)	109.53 ± 3.13	192.80 ± 14.34	83.28 ± 14.49
Group 2 (Diabetic Control)	133.75 ± 14.41	212.11 ± 17.24	78.36 ± 9.15
Group 3 (Metformin)	118.33 ± 5.23	178.58 ± 11.19	66.20 ± 9.74
Group 4 (100 mg/kg)	118.36 ± 12.64	176.67 ± 18.24	58.31 ± 9.52^{a}
Group 5 (200 mg/kg)	112.04 ± 4.43	153.99 ± 5.54	41.95 ± 1.45^{a}
Group 6 (500 mg/kg)	125.81 ± 6.59	211.08 ± 15.88	85.27 ± 9.29

Values are expressed as mean ± SEM (n = 6). Superscript a indicates a significant difference ($p < 0.05$) from the normal control.

Effect of J. carnea on organ weights (pancreas, liver, and kidney): Table 5 presents the final organ weights. The diabetic untreated group (Group 2) exhibited a marked increase in liver weight compared to the other groups. Pancreas and kidney weights did not differ significantly between normal and diabetic controls ($p > 0.05$). Treatment with *J. carnea* extract and metformin reduced liver weight towards normal values.

Table 5: Weights of the pancreas, liver, and kidney

Group	Pancreas (g)	Liver (g)	Kidney (g)
Group 1 (Control)	0.68 ± 0.10	4.57 ± 0.18^{b}	1.14 ± 0.09
Group 2 (Diabetic Control)	0.63 ± 0.06	8.04 ± 0.58^{a}	1.43 ± 0.18
Group 3 (Metformin)	0.37 ± 0.06^{ab}	4.44 ± 0.28^{b}	0.77 ± 0.11^{ab}
Group 4 (100 mg/kg)	0.36 ± 0.03^{ab}	3.53 ± 0.34^{ab}	0.66 ± 0.03^{ab}
Group 5 (200 mg/kg)	0.25 ± 0.00^{ab}	3.78 ± 0.09^{b}	0.67 ± 0.04^{ab}
Group 6 (500 mg/kg)	0.33 ± 0.03^{ab}	4.18 ± 0.23^{b}	0.76 ± 0.05^{ab}

Values are expressed as mean ± SEM (n=6). Values with superscript "a" are significantly different from the normal control, while values with superscript "b" are significantly different from the diabetic control ($p < 0.05$). Values with superscripts "ab" are significantly different from both normal and diabetic controls ($p < 0.05$) but not significantly different when compared to the Metformin-treated groups.

Effects of methanol extract of J. carnea leaves on the pancreas, liver and kidney ultrastructure in STZ-induced diabetic rats: The histopathological analyses of the Pancreas, Liver, and Kidney of diabetic rats treated with methanol extracts of the leaves *of J. carnea* are presented in Figures 1,2, and 3, respectively.

Fig. 1a - 1f represent the photomicrographs of the Pancreas

Fig. 2a - 2f represent the photomicrographs of the Liver

Fig. 3a - 3f represent the photomicrographs of the Kidney

Fig. 1a Pancreas of group 1 rats (Normal control) showing normal Exocrine Acini (EA), Islets of Langerhans (IL), Pancreatic ducts (PD): H&E x 400

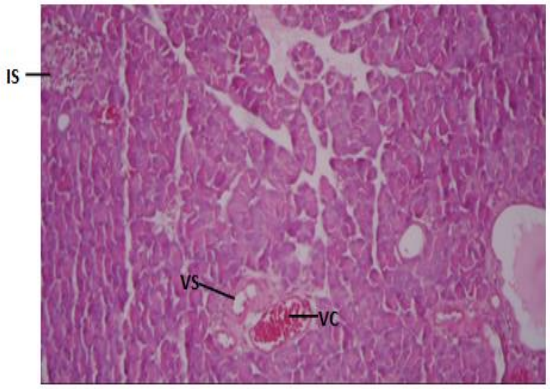

Fig. 1b. Pancreas of diabetic untreated rats (Group 2) showing degenerating islets (IS), vascular congestion (VC) and stenosis (VS): H&E x 400

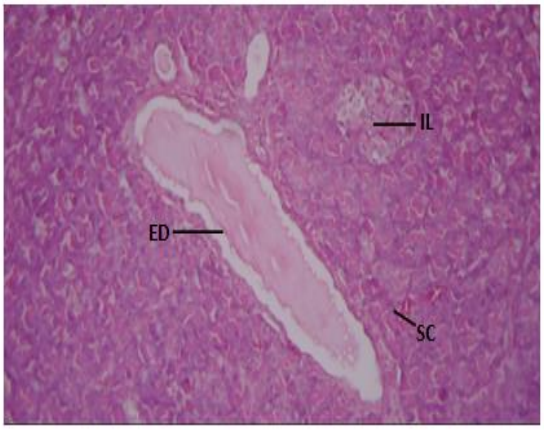

Fig. 1c. Pancreas of metformin treated diabetic rat (Group 3) showing normal islet of Langerhans (IL), dilated exocrine duct (ED) with active stromal congestion (SC): H&E x 400

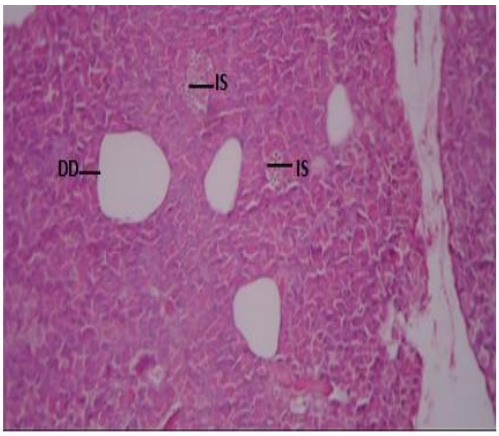

Fig. 1d. Pancreas of diabetic rats treated with 100mg/kg bw extract (Group 4) showing regenerating islets (IS) and dilated, ducts (DD): H&E x 400

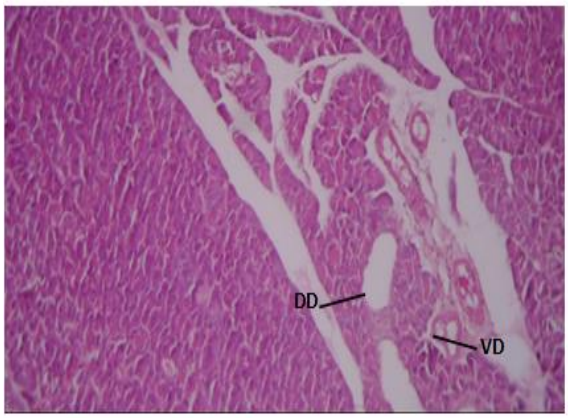

Fig. 1e. Pancreas of diabetic rats treated with 200mg/kg bw extract (Group 5) showing paucity of islets, dilated ducts (DD), and vascular obstruction (VD): H&E x 400

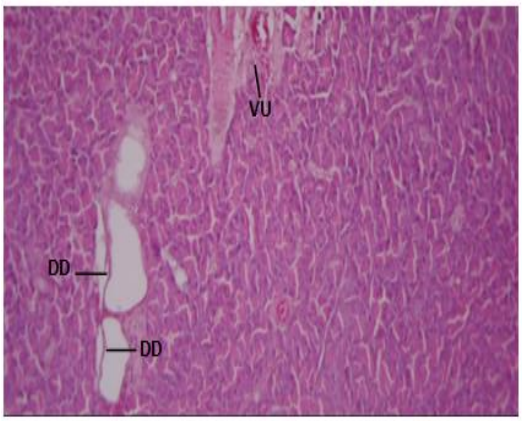

Fig.1f. Pancreas of diabetic rats treated with 500mg/kg bw extract (Group 6) showing: paucity of islets, dilated ducts (DD), and vascular ulceration (VU): H&E x 400

Fig. 1: Photomicrographs of the pancreas

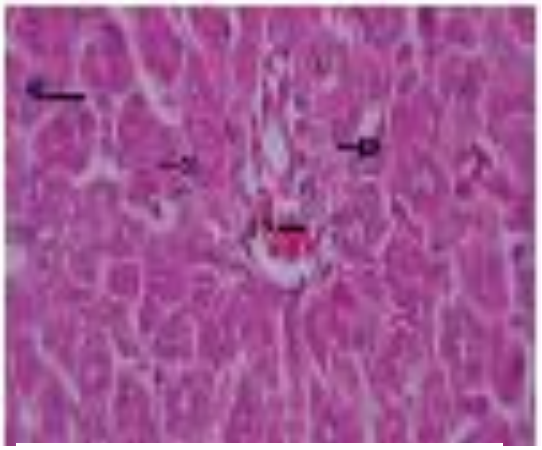

Fig. 2a. Liver of group 1 rats (Normal control) showing normal architecture: hepatocytes. (HC), sinusoids (SI), bile duct (BD), portal vein (PV): H&E x 400

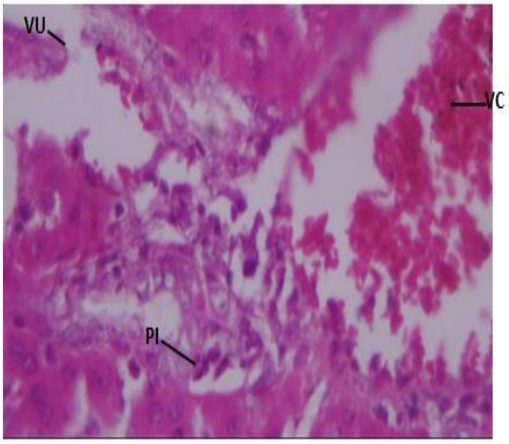

Fig. 2b. Liver of diabetic untreated rats (Group 2) showing: severe vascular ulceration (VU), congestion (VC), periportal infiltrates of inflammatory cells (PI): H&E x 400

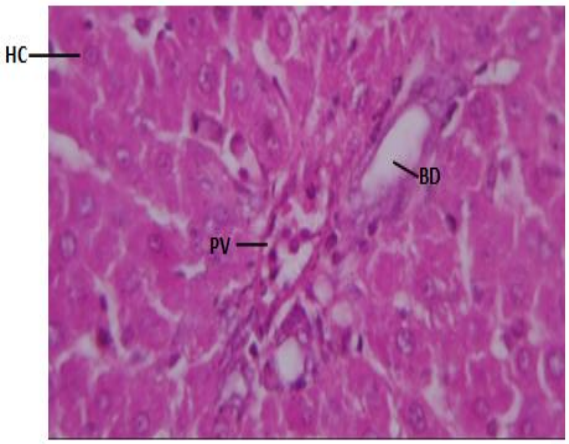

Fig. 2c. Liver of metformin treated diabetic rat (Group 3) showing normal hepatocytes (HC), portal vein (PV), and bile ducts (BD) H&E x 400

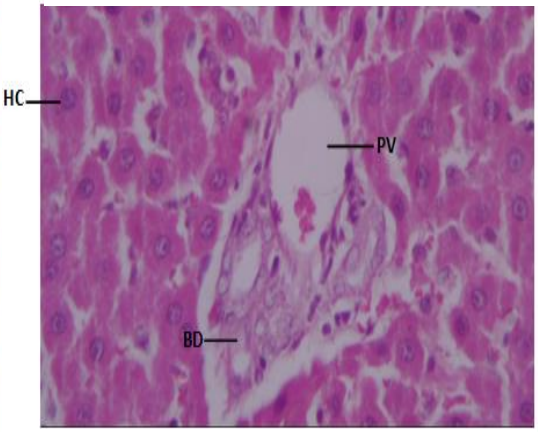

Fig. 2d. Liver of diabetic rats treated with 100mg/kg bw extract (Group 4) showing: normal architecture of hepatocytes (HC), portal vein (PV), and bile ducts (BD): H&E x 400

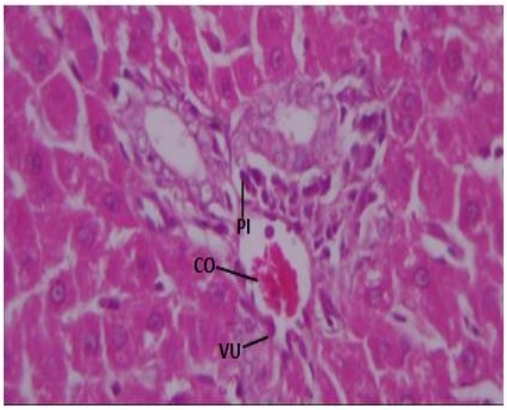

Fig. 2e. Liver of diabetic rats treated with 200mg/kg bw extract (Group 5) showing: periportal infiltrates of inflammatory cells (PI), focal portal vascular ulceration (VU), congestion (CO): H&E x 400

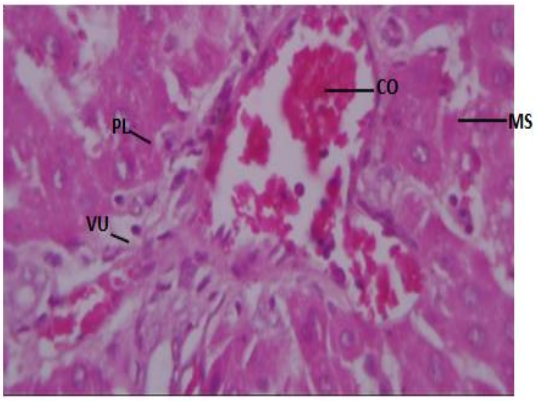

Fig. 2f. Liver of diabetic rats treated with 500mg/kg bw extract (Group 6) showing: mild periportal mobilization of lymphocytes, vascular ulceration, congestion, microvesicular steatosis: H&E x 400

Figure. 2: Photomicrographs of the liver

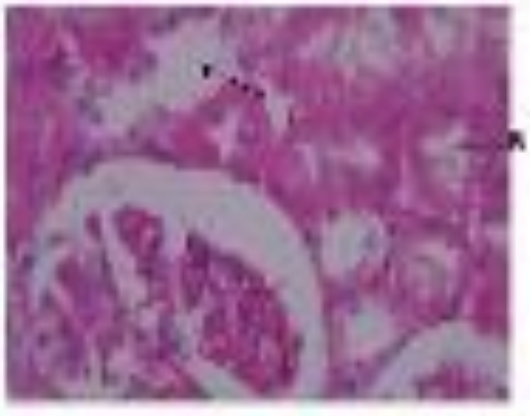

Fig. 3a. Kidney of group 1 rats (Normal control) showing normal architecture: interstitial space (IS),

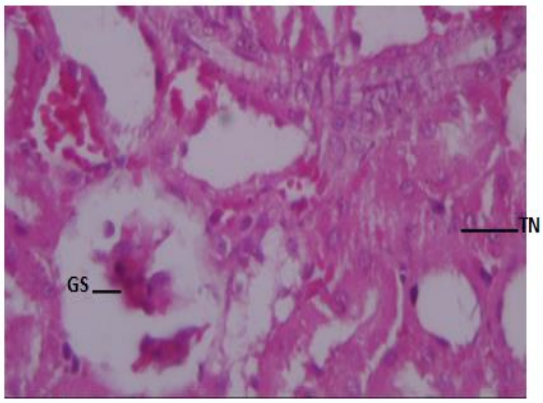

Fig. 3b Kidney of untreated diabetic rats (Group 2) showing: interstitial congestion, glomerular shrinkage (GS), focal (tubular necrosis (TN): H&E x 400

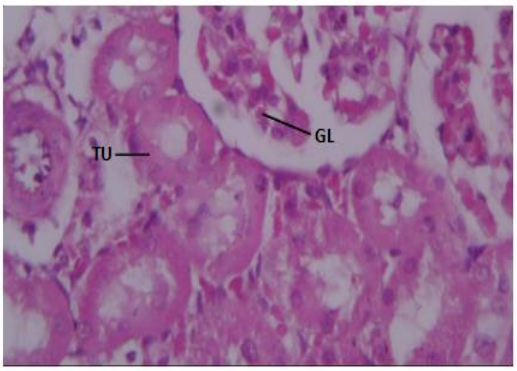

Fig. 3c Kidney of metformin treated diabetic rat (Group 3) showing normal tubules (TU) and normal glomeruli (GL), (H&E x 400).

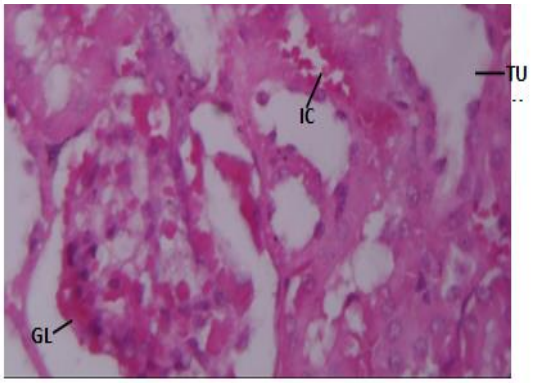

Fig. 3d. Kidney of diabetic rats treated with 100mg/kg bw extract (Group 4) showing: active interstitial congestion (IC), tubules, glomeruli (GL), all normal: H&E x 400

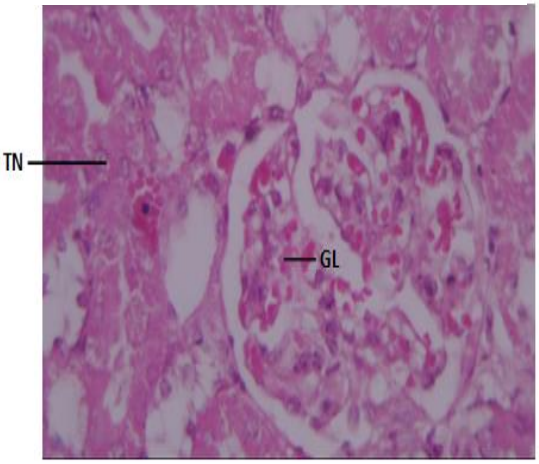

Fig. 3e. Kidney of diabetic rats treated with 200mg/kg bw extract (Group 5) showing: focal tubular necrosis (TN), and normal glomerulus (GL): H&E x 400

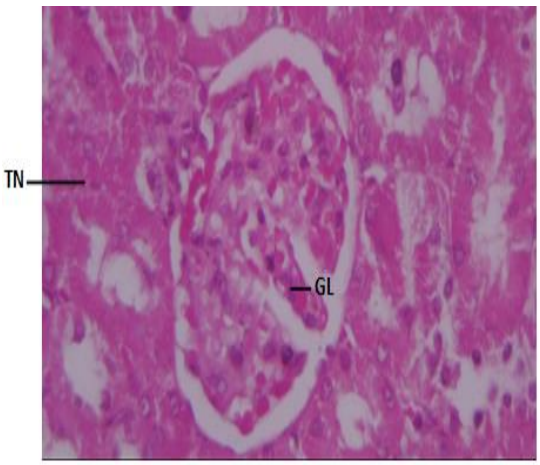

Fig. 3f. Kidney of diabetic rats treated with 500mg/kg bw extract (Group 6) showing: mild focal tubular necrosis (TN), and normal glomerulus (GL): H&E x 400

Histopathological examination of the pancreas in normal control rats (Group 1) revealed well-preserved islets of Langerhans, intact exocrine acini, and normal pancreatic ducts (Fig. 1a). In contrast, untreated diabetic rats (Group 2) exhibited marked pancreatic degeneration characterized by vascular obstruction, tissue ulceration, and partial to complete loss of islet architecture, indicating severe STZ-induced β-cell damage (Fig. 1b). Metformin-treated rats (Group 3) showed substantial restoration of pancreatic architecture, with evident regeneration of

islets of Langerhans comparable to normal controls (Fig. 1c). Similarly, administration of *Justicia carnea* extract at 100 mg/kg body weight (Group 4) produced pronounced islet regeneration and improved pancreatic integrity (Fig. 1d). Although higher doses (200 and 500 mg/kg bw; Groups 5 and 6) also elicited regenerative responses (Fig. 1e,f), the extent of islet restoration was comparatively reduced and accompanied by residual vascular abnormalities, including congestion and dilation.

The liver of normal control rats (Group 1) displayed normal histoarchitecture, with well-arranged hepatocytes, intact sinusoids, central veins, bile ducts, and portal triads (Fig. 2a). In diabetic control rats (Group 2), there were pronounced pathological alterations, including vascular dilatation, congestion, hepatocellular apoptosis, and inflammatory cell infiltration (Fig. 2b), Treatment with metformin (Group 3) markedly reversed these alterations, restoring near-normal hepatic morphology (Fig. 2c). Similarly, *J. carnea* extract at 100 mg/kg bw (Group 4) effectively ameliorated hepatic damage, with restoration of hepatocyte architecture and reduction of inflammatory infiltration (Fig. 2d). Although higher doses (200 and 500 mg/kg bw; Groups 5 and 6) also improved hepatic histology (Fig. 2e, 2f), mild inflammatory cell infiltration and occasional vascular congestion persisted.

Renal histology of normal control rats (Group 1) showed intact glomeruli, well-formed renal tubules, and normal interstitial spaces (Fig. 3a). In contrast, untreated diabetic rats (Group 2) exhibited severe structural alterations, including glomerular shrinkage, interstitial congestion, and tubular necrosis, consistent with STZ-induced diabetic nephropathy (Fig. 3b). Metformin treatment (Group 3) restored normal renal architecture, with preservation of glomerular and tubular structures (Fig. 3c). Likewise, rats treated with 100 mg/kg bw of *J. carnea* extract (Group 4) demonstrated marked renoprotection, with near-normal histological appearance comparable to the metformin group (Fig. 3d). However, higher doses (200 and 500 mg/kg bw; Groups 5 and 6) provided only partial protection, as evidenced by focal tubular necrosis, although glomerular architecture remained largely intact (Fig. 3e, 3f).

Discussion

Diabetes mellitus (DM) is a group of metabolic disorders increasingly prevalent worldwide, characterised by multiorgan complications including peripheral neuropathy, retinopathy, nephropathy, hyperlipidemia, and various cardiovascular disorders (Gilbert and Krum, 2015; Smith and Jane, 2020; Suman *et al*., 2023). Previous studies have demonstrated the antidiabetic potential of Justicia carnea extracts (Ukpabi-Ugo *et al*., 2019; Ojeaburu and Olasehinde, 2024; Ukpabi-Ugo *et al*., 2024). In this present study, rats treated with 100 mg/kg bw of *J. carnea* extract showed marked regeneration of the islets, effectively ameliorating diabetes-induced damage. Higher doses of 200 and 500 mg/kg bw also showed regenerative effects; however, the extent of islet restoration was comparatively lower, with residual vascular abnormalities such as dilation and obstruction. These observations suggest that the extract may induce proliferation of quiescent β-cells to replace lost cells, consistent with prior findings on ethanol extracts of *Alchornea cordifolia* in alloxan-induced diabetic rats (Eliakim-Ikechukwu and Obri, 2009).

The liver of normal control rats exhibited well-preserved hepatic architecture, including normal hepatocytes, sinusoids, central veins, bile ducts, and portal zones

Interestingly, the 100 mg/kg dose appeared more effective in ameliorating STZ-induced hepatic damage than the higher doses, highlighting a potential optimal dose-response relationship. These findings align with previous studies demonstrating hepatoprotective effects of *J. carnea* extract in diabetic animal models (Wilson *et al*., 2021; Ukpabi-Ugo *et al*., 2023).

Diabetic nephropathy is a major microvascular complication of DM and a leading cause of end-stage renal disease (Rabkin, 2003; Umanath, 2018). In the present study, normal control rats exhibited intact glomeruli, tubules, and interstitial spaces. Untreated diabetic rats showed interstitial congestion, glomerular shrinkage, and tubular necrosis, consistent with STZ-induced nephropathy (Umanath, 2018; Ahmadi, 2024). Rats treated with 100 mg/kg bw of *J. carnea* extract exhibited normal glomerular and tubular structure, comparable to that of metformin-treated rats. Higher doses (200 and 500 mg/kg bw) demonstrated partial protection, with focal necrosis but no glomerular shrinkage. All doses of *J. carnea* extract evaluated in this study demonstrated significant efficacy in mitigating diabetes-induced nephrotoxicity, thereby corroborating prior findings by Ukpabi-Ugo *et al*. (2018) and Ojeaburu and Olasehinde (2024) regarding its renoprotective properties.

Conclusion

The present study provides compelling histopathological evidence of the therapeutic potential of *Justicia carnea* methanol leaf extract in mitigating diabetes-associated organ damage in a streptozotocin-induced diabetic rat model. The extract elicited dose-dependent restoration of normal tissue architecture in the pancreas, liver, and kidneys, with the highest dose (500 mg/kg body weight) demonstrating the most robust protective and regenerative effects, often comparable to or surpassing those observed with metformin (50 mg/kg). These findings substantiate the ethnomedicinal use of *J. carnea* as an antidiabetic agent and underscore its ability to attenuate hyperglycemia-induced histopathological injury in key metabolic organs. The observed organ-protective actions likely reflect the combined antioxidant, anti-inflammatory, and possible insulin-sensitising or β-cell regenerative properties of its bioactive constituents. In conclusion, *Justicia carnea* methanol leaf extract holds considerable promise as a phytotherapeutic candidate for the management of diabetes mellitus and the prevention of its debilitating complications. Further preclinical studies elucidating the underlying molecular mechanisms, long-term toxicity profiles, and bioactive compound isolation, followed by well-designed clinical trials, are essential to translate these findings into safe and effective therapeutic or adjunctive applications in human diabetes care.

Declaration of competing interest

The authors declare no conflicts of interest related to the publication of this study.

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