

Research Article

Therapeutic Effects of the Aqueous Extract of *Desmodium adscendens* (Fabaceae) on Type 2 Diabetes Complications in Wistar Rats

Franck Yvan Djientcheu Deugoue^{1, 2} , Arnaud Galvani Nekam¹ ,
Henri Tetang¹ , Lohik Mbolang Nguegan¹ ,
Aicha El-Ramadan Malane Nsangou¹ , Madeleine Chantal Ngougoure¹ ,
Mireille Kameni Poumeni³ , Yolande Sandrine Mengue Ngadena¹ ,
Dieudonne Pascal Chuisseu Djamen⁴ , Paul Desire Dzeufiet Djomeni^{1, *} 

¹Department of Animal Biology and Physiology, University of Yaounde I, Yaounde, Cameroon

²Department of Physiology, University of Yaounde I, Yaounde, Cameroon

³Department of Microbiology and Parasitology, University of Bamenda, Bambili, Cameroon

⁴Higher Institute of Health Sciences, University of Mountains, Bangangte, Cameroon

Abstract

Diabetes mellitus is a metabolic disease caused by impaired insulin secretion and/or abnormalities in insulin action on target tissues. Many plants have been shown to be effective in treating diabetes. This study aimed to assess the anti-diabetic activity and antioxidant potential of the aqueous extract of *Desmodium adscendens* in type 2 diabetic rats. Diabetes was induced by prolonged sucrose administration, followed by a single injection of streptozotocin (STZ, at 40 mg/kg). The diabetic rats were then separated into four groups and given different treatments. The first group received distilled water (10 mL/kg), the second group received metformin (200 mg/kg), and the third and fourth groups received aqueous extract of *D. adscendens* at 100 and 200 mg/kg, respectively. A fifth group of healthy rats received only distilled water (10 mL/kg). After 28 days of treatment, the animals were sacrificed, and their serum was used for biochemical analysis. The tissue parameters of oxidative stress were evaluated, and histology was performed. Diabetes caused a significant increase ($p < 0.001$) in blood sugar, triglyceride and total cholesterol levels, in transaminases and alkaline phosphatase (ALP) activities, a significant increase ($p < 0.05$) in creatinine level, as well as a significant variation ($p < 0.001$) in tissue parameters of oxidative stress in untreated diabetic rats compared to normal rats. Sucrose and STZ also caused disorganization of the hepatocytes, congestion of the portal vein, thickening of the aortic media and renal mesangial expansion in histological analysis. The aqueous extract of *D. adscendens* decreases blood glucose levels, inhibits lipid peroxidation and free radicals production, enhances antioxidant capacity and ameliorates the structure of organs that have been disorganized by diabetes. The aqueous extract of *D. adscendens* enhances diabetic conditions and prevents diabetes-related complications by exhibiting hypoglycemic, hypolipidemic, and antioxidant properties.

Keywords

Diabetes, Oxidative Stress, *Desmodium Adscendens*, Rat, Sucrose, Streptozotocin

*Corresponding author: dzeufiet@yahoo.fr (Paul Desire Dzeufiet Djomeni)

Received: 13 September 2025; **Accepted:** 28 September 2025; **Published:** 27 October 2025



1. Introduction

Diabetes mellitus is a metabolic disorder characterized by consistently high levels of blood sugar caused by a lack of insulin secretion, insulin resistance, or a combination of both [1]. It is a complex and multifactorial syndrome that affects the metabolism of carbohydrates, fats, and proteins, leading to hyperglycemia and hyperlipidemia [2]. Some of the main risk factors for developing type 2 diabetes mellitus include genetic predisposition, a high-calorie diet, a sedentary lifestyle, and obesity [3, 4]. According to the International Diabetes Federation (IDF), there were 589 million people worldwide living with diabetes in 2024, and if no action is taken, approximately 853 million adults will be affected by 2050 [5]. The chronic hyperglycemic state of diabetes mellitus leads to the development of severe complications, which are a major cause of premature morbidity and mortality in diabetic patients [6]. Despite treatment protocols, maintaining proper glycemic control remains a challenge. This glycemic instability is associated with the significant production of reactive oxygen species (ROS) [7], leading to oxidative stress that plays a key role in the onset and severity of complications [8, 9].

Oxidative stress triggers the production of inflammatory agents that boost the generation of free radicals [10]. Although free radicals are important for biological homeostasis, oxidative stress plays a crucial role in various complications of diabetes by causing lipid peroxidation, DNA damage, and protein and mitochondrial dysfunction [8, 9]. Most biological cells have an inherent defence mechanism that uses various enzymes to protect themselves from free radical damage [9]. Still, these mechanisms fail in the case of diabetes. In hyperinsulinism, insulin exposure causes a significant increase in superoxide anion (O_2^-) in the endothelial cells [11], inhibition of catalase and stimulation of hydrogen peroxide (H_2O_2) production, leading to tissue overproduction of ROS that disrupt and inhibit insulin secretion [12]. ROS also contribute to insulin resistance by blocking insulin signal transduction, which inhibits the translocation of the Glucose Transporter 4 receptor, preventing glucose from entering the cell [13]. Since oxidative stress and inflammation are major drivers in the development of diabetic complications, emerging therapies target these crucial pathways to alleviate the burden of these diseases [6, 8].

Diabetes and associated diseases are highly prevalent in the world's population, making it crucial to research the molecular mechanisms, prevention, and treatment of these ailments [14]. While synthetic drugs have made significant scientific advancements in managing diabetes, the need for new natural compounds remains [15, 16]. Traditional medicinal plants have become increasingly popular due to their positive effect on health, specifically their effectiveness against diabetes mellitus and cardiovascular disease [17]. The use of traditional pharmacology is also encouraged by historical, cultural, and economic factors. Additionally, the World Health Or-

ganization (WHO) recognizes the efficacy of plants in treating various diseases, including diabetes mellitus [18].

Medical plants and their bioactive components are widely used worldwide to manage chronic diseases, such as type 2 diabetes mellitus, and their associated complications. *Desmodium adscendens* (*D. adscendens*) is one such plant, which is an herbaceous biennial plant that grows in the humid equatorial zones. It has been used empirically for many years in different parts of the world, particularly in West and Central Africa (Ghana, Cameroon), as an anti-asthmatic, anti-spasmodic, analgesic, depurative, and diuretic [19, 20]. Additionally, *D. adscendens* is used for liver protection and as an anti-inflammatory, based on the synergy between several molecules, including saponins, anthocyanins, flavonoids, tannins, terpenoids, and unsaturated fatty acids [20]. However, to date, there have been no scientific studies conducted on the therapeutic properties of *D. adscendens* on diabetes and its complications. Therefore, this study was carried out to examine the beneficial properties of *D. adscendens* on oxidative stress and other complications in type 2 diabetes induced by a high-fat diet and streptozotocin (STZ) in rats.

2. Materials and Methods

2.1. Animal Material

A group of sixty-day-old male Wistar rats, weighing between 165-185 g, were kept in collective plastic cages. The cages were lined with wood chips and cleaned daily at the animal house of the Laboratory of Animal Physiology at the University of Yaoundé I. These rats were kept at room temperature, with access to water and food. They were treated following the guidelines set by the Cameroonian Bioethics Committee (registration number FWA-IRB00001954).

2.2. Plant Extraction

In November 2011, the aerial parts of *D. adscendens* were collected from the Centre region in Cameroon. The specimen was identified by comparing it with the collector number Fotius G. 3093 of the Cameroon National Herbarium Collection N°41122/HNC (YA). An extract was prepared using the process described by Djientcheu *et al.* [21], which resulted in a yield of 12%.

2.3. Qualitative Phytochemistry of the Extract

The Ayoola *et al.* [22] protocol was used to identify bioactive compounds eventually present in our plant, like alkaloids, flavonoids, anthocyanins, and polyphenols in our plant.

2.4. Type 2 Diabetes Induction

For the induction of diabetes, we used the sucrose/STZ model. Fifty normoglycemic rats were divided into two groups: group 1 with six animals and group 2 with forty-four animals. The induction protocol we followed was described in the study by Djientcheu *et al.* [21]. Group 1 received 10 mL/kg of distilled water, while group 2 received 10 mL/kg of sucrose 50% by gavage and sucrose 10% in drinking water. At the end of the induction period, animals in group 2 with a fasting blood glucose level of at least 200 mg/dL were considered diabetic [23] and were used for the rest of the experiment.

2.5. Distribution of Animals and Treatment

The study involved twenty-six diabetic rats that were randomly divided into four subgroups. Each subgroup was given a daily oral dose of either distilled water at 10 mL/kg (negative control, NC), metformin at 200 mg/kg (MET), or the aqueous extract of *D. adscendens* at 100 and 200 mg/kg (Da 100 and Da 200) for 28 days. Group 1 animals, which were normoglycemic, served as the healthy control (HC) and received distilled water at 10 mL/kg. All groups had free access to water and food, which was lead-free. The glycaemia level of each rat was monitored every seven days for 28 days during the treatment period.

2.6. Sacrifice, Sample Collection and Histology

At the end of the treatment period, the animals were sacrificed by decapitation under anaesthesia. Arteriovenous blood was collected in dry tubes, which were then centrifuged at 4 °C for 15 minutes at 3000 rpm. The serum that was extracted was stored at -20 °C so that glucose level, lipid parameters, alkaline phosphatase, transaminases, creatinine, and proteins could be determined later using Fortress Diagnostics kits. The atherogenic index (AI) has also been calculated according to Dobiášová & Frohlich's formula (1) [24]:

$$AI = \text{Log}\left(\frac{\text{Triglycerides}}{\text{HDLc}}\right) \quad (1)$$

The liver, kidney, aorta, and sciatic nerve were collected and fixed in formalin for histological sections as described by Smith and Bruton [25]. Additionally, oxidative stress parameters such as catalase [26], Superoxide Dismutase (SOD) [27], Glutathione (GSH), nitrites [28] and Malondialdehyde (MDA) [29] were evaluated.

The histological sections were observed using a computer-assisted microscope (*Scientico STM-50*) with a digital camera (*DCM 35: 350 K pixels*). Microphotographs were taken using Minisee software (*Micrometrics 122 CU*). For histomorphometry, the aorta and adrenal gland slices were measured five times for each parameter (intima and media or fasciculate zone and adrenal cortex respectively), and the

average value for each group was obtained. This measurement was performed using a surface measurement program (*Image J Version 1.32j*).

2.7. Statistical Analysis

The results were presented as mean value with Standard Error on the Mean (SEM) and analyzed using GraphPad Prism software version 5.03. To compare the different groups, the one-way ANOVA test of variance followed by Tukey's multiple comparison post-test was used, with a significance threshold set at 0.05.

3. Results

3.1. Phytochemical Analysis of the Aqueous Extract of *Desmodium adscendens*

The qualitative phytochemical screening of the aqueous extract of *D. adscendens* revealed the presence of different classes of compounds such as alkaloids, flavonoids, polyphenols, anthraquinones, glycosides, saponins and triterpenes. However, anthocyanins, steroids and tannins were absent (Table 1).

3.2. Flow Chart

Out of 44 animals that began the diabetes induction process, a success rate of 72.2% was observed. The death rate in the diabetic group was 23.1% (Figure 1).

3.3. Effects of *Desmodium Adscendens* on the Blood Glucose Level of Diabetic Rats

At the treatment initiation, the mean blood glucose level of NC group rats was significantly higher ($p < 0.001$) than that of HC one (333.00 ± 15.91 vs 89.50 ± 8.39) (Figure 2). After 14 days of treatment, the blood glucose levels in *D. adscendens* treated groups (Da 100 and Da 200) were significantly lower ($p < 0.001$) than in the NC group. At the end of the treatment, the levels of blood glucose in both the Da 100 and MET groups were similar to those in the HC group. The most effective dose of extract was 100 mg/kg with a decrease of 66.7% as compared to the NC group at the end of the treatment (day 28).

3.4. Effects of *Desmodium Adscendens* Aqueous Extract on Lipid Parameters

Diabetes significantly ($p < 0.001$) increased total cholesterol as well as Low Density Lipoprotein (LDL) and triglyceride concentrations and decreased High Density Lipoprotein (HDL) in the NC rats in comparison to those of HC group (Figure 3A & 3B). Rats treated with both aqueous extract and metformin had a significant ($p < 0.001$) decrease in the total

cholesterol, LDL and triglyceride concentration, and increased in HDL concentration ($p < 0.05$ and $p < 0.01$) compared to the NC, bringing them near the normal levels. The

atherogenic index distribution in each group was similar to that of total cholesterol.

Table 1. Qualitative phytochemical screening of the aqueous extract of *D. adscendens*.

Com- pounds	Alka- loids	Anthocya- nins	Anthra- quinones	Flavonoids	Glyco- sides	Polyphe- nols	Sapo- nins	Ster- oids	Tan- nins	Triter- penes
Status	P	A	P	P	P	P	P	A	A	P

A: Absent; P: Present

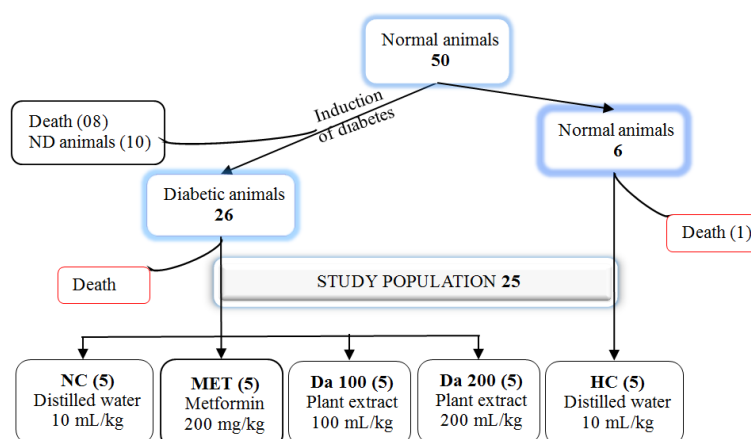


Figure 1. Study flow chart.

HC: Healthy control; NC: Negative control; ND: Non-diabetics; MET: animals receiving metformin; Da 100 and Da 200: animals receiving *D. adscendens* extract at the doses of 100 and 200 mg/kg respectively.

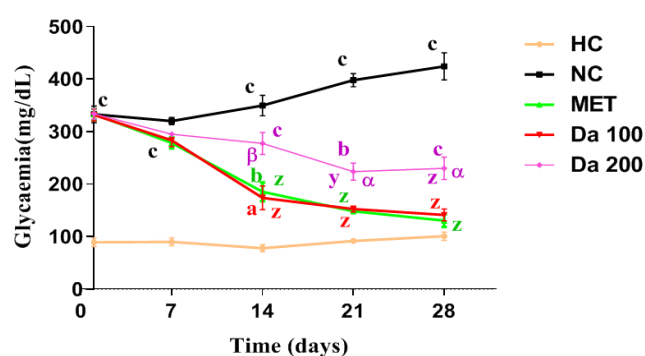


Figure 2. Effect of the aqueous extract of the leaves of *D. adscendens* on blood sugar levels of rats.

HC: Healthy control, NC: Negative control, MET: animals receiving metformin, Da 100 and Da 200: animals receiving *D. adscendens* extract at the doses of 100 and 200 mg/kg respectively. ^a $p < 0.05$, ^b $p < 0.01$, ^c $p < 0.001$ significant difference in comparison to HC, ^y $p < 0.001$, ^z $p < 0.001$ significant difference from NC, ^a $p < 0.05$, ^β $p < 0.01$ significant difference from MET.

3.5. Effects of *Desmodium Adscendens* Extract on Liver and Kidney Functions

Diabetes induced a significant increase in transaminase ($p < 0.001$), alkaline phosphatase (ALP) activities ($p < 0.001$) and creatinine ($p < 0.05$) levels and a significant decrease ($p < 0.001$) in total serum protein compared to HC rats (Table 2). The extract at both doses resulted in dose-dependent normalization of transaminase and creatinine levels, while it significantly ($p < 0.001$) reduced ALP activity compared to the NC group. The extract did not affect protein levels, for which only metformin allowed a significant increase ($p < 0.01$) compared to the NC group.

3.6. Effects of *Desmodium Adscendens* Extract on Oxidative Stress Parameters

3.6.1. Effects on Malondialdehyde Concentration

Diabetes resulted in a significant ($p < 0.001$) increase in the concentration of malondialdehyde (MDA) in the liver, kidney, aorta and sciatic nerve of animals in the NC group compared

to the HC (Table 3). The aqueous extract of *D. adscendens*, as well as metformin, resulted in the normalization of this con-

centration in the aorta and sciatic nerve.

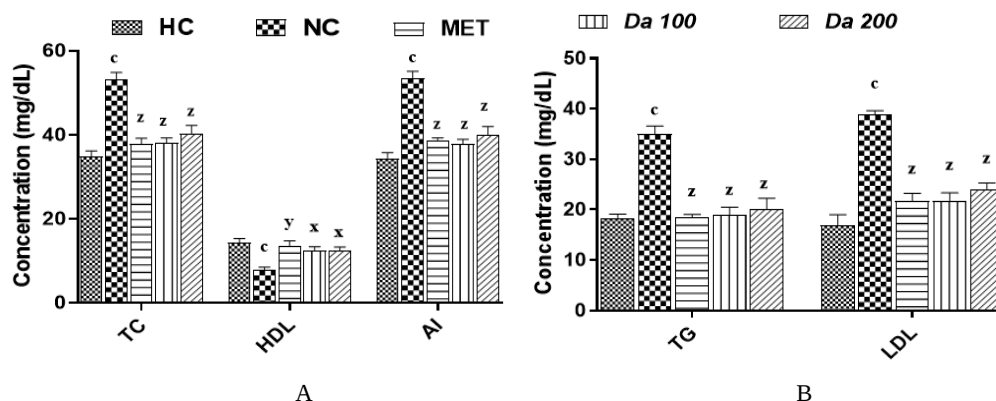


Figure 3. Effect of aqueous extract of *D. adscendens* on total cholesterol and triglyceride levels.

Each bar represents the mean $\pm$ SEM (n = 5), AI: Atherogenic Index, HDL: High-Density Lipoprotein, LDL: Low-Density Lipoprotein, TC: Total Cholesterol, TG: Triglycerides, HC: Healthy control, NC: Negative control, MET: animals receiving metformin, Da 100 and Da 200: animals receiving *D. adscendens* extract at the doses of 100 and 200 mg/kg respectively. ^c p < 0.001 significant difference in comparison to HC, ^x p < 0.05, ^y p < 0.01, ^z p < 0.001 significant difference from NC.

Table 2. Effect of aqueous extract of *D. adscendens* on some biochemical parameters.

Parameters	HC	NC	MET	Da 100	Da 200
SGPT (U/L)	18.24 $\pm$ 1.13	34.82 $\pm$ 2.39 ^c	17.83 $\pm$ 1.29 ^z	18.07 $\pm$ 0.90 ^z	20.04 $\pm$ 2.07 ^z
SGOT (U/L)	23.40 $\pm$ 1.65	40.67 $\pm$ 1.86 ^c	24.32 $\pm$ 2.76 ^z	24.56 $\pm$ 1.30 ^z	27.67 $\pm$ 2.84 ^y
ALP (U/L)	10.19 $\pm$ 0.59	16.31 $\pm$ 1.08 ^c	5.74 $\pm$ 0.71 ^{bz}	5.03 $\pm$ 0.56 ^{bz}	5.30 $\pm$ 0.68 ^{bz}
Total proteins (mg/dL)	7.74 $\pm$ 0.46	5.24 $\pm$ 0.31 ^c	7.00 $\pm$ 0.25 ^y	5.93 $\pm$ 0.28 ^b	6.47 $\pm$ 0.14
Creatininemia (mg/dL)	203.20 $\pm$ 10.60	247.70 $\pm$ 8.89 ^a	185.80 $\pm$ 7.87 ^y	176.20 $\pm$ 7.98 ^z	198.10 $\pm$ 11.53 ^x

Each value represents the mean $\pm$ SEM (n = 5), ALP: Alkaline phosphate; SGPT: Serum Glutamo Pyruvate Transferase; SGOT: Serum Glutamo Oxaloacetate Transferase; HC: Healthy control, NC: Negative control, MET: animals receiving metformin, Da 100 and Da 200: animals receiving *D. adscendens* extract at the doses of 100 and 200 mg/kg respectively. ^a p < 0.05 ^b p < 0.01 ^c p < 0.001 significant difference in comparison to HC group, ^x p < 0.05, ^y p < 0.01, ^z p < 0.001 significant difference from NC.

Table 3. Effects of *D. adscendens* extract on MDA concentration in nmol/mg of organ.

Groups	Liver	Kidney	Aorta	Sciatic nerve
HC	0.012 $\pm$ 0.003	0.081 $\pm$ 0.006	0.083 $\pm$ 0.011	0.096 $\pm$ 0.011
NC	0.182 $\pm$ 0.011 ^c	0.127 $\pm$ 0.005 ^c	0.424 $\pm$ 0.030 ^c	0.229 $\pm$ 0.016 ^c
Met	0.095 $\pm$ 0.008 ^{cz}	0.087 $\pm$ 0.006 ^y	0.131 $\pm$ 0.018 ^z	0.091 $\pm$ 0.012 ^z
Da 100	0.105 $\pm$ 0.009 ^{cz}	0.101 $\pm$ 0.007 ^x	0.134 $\pm$ 0.023 ^z	0.103 $\pm$ 0.012 ^z
Da 200	0.109 $\pm$ 0.011 ^{cz}	0.113 $\pm$ 0.003 ^b	0.143 $\pm$ 0.024 ^z	0.123 $\pm$ 0.012 ^z

Each value represents the mean $\pm$ SEM (n = 5), Da: *D. adscendens*, HC: Healthy control, NC: Negative control, Met: animals receiving metformin, Da 100 and Da 200: animals receiving Da extract at the doses of 100 and 200 mg/kg, MDA: Malondialdehyde, ^b p < 0.01 ^c p < 0.001: significant difference from HC, ^x p < 0.05 ^y p < 0.01 ^z p < 0.001: significant difference from NC.

3.6.2. Effects on Nitrite Concentration

Diabetes resulted in a significant ($p < 0.001$) increase in nitrite concentration in the liver by 300% and a significant ($p < 0.001$) decrease in the kidney and aorta by 80.0% and 65.5%, respectively, compared to the Healthy control group (Table 4). These concentrations were normalized by the administration of the different treatments.

3.6.3. Effects on Reduced Glutathione Concentration

Diabetes has led to a significant decrease in the concentration of GSH in the liver ($p < 0.05$), kidney ($p < 0.01$), aorta ($p < 0.001$) and sciatic nerve ($p < 0.001$). The extract normalized the GSH concentration in these organs and this correction was dose-dependent in the liver and kidney (Table 5).

Table 4. Effects of *D. adscendens* extract on nitrite concentration in $\mu\text{mol/L}$.

Groups	Liver	Kidney	Aorta
HC	13.061 $\pm$ 2.486	55.467 $\pm$ 6.235	55.166 $\pm$ 3.830
NC	52.116 $\pm$ 5.001 ^c	11.091 $\pm$ 2.971 ^c	19.307 $\pm$ 3.240 ^c
Met	10.579 $\pm$ 2.700 ^z	54.499 $\pm$ 6.222 ^z	57.435 $\pm$ 6.256 ^z
Da 100	11.998 $\pm$ 2.447 ^z	51.863 $\pm$ 6.823 ^z	54.837 $\pm$ 4.879 ^z
Da 200	12.240 $\pm$ 2.504 ^z	46.402 $\pm$ 9.378 ^z	46.433 $\pm$ 5.148 ^z

Each value represents the mean $\pm$ SEM ($n = 5$), *Da*: *D. adscendens*, *HC*: Healthy control, *NC*: Negative control, *Met*: animals receiving metformin, *Da 100* and *Da 200*: animals receiving *Da* extract at the doses of 100 and 200 mg/kg, ^c $p < 0.001$: significant difference from HC, ^z $p < 0.001$: significant difference from NC.

Table 5. Effect of *D. adscendens* on GSH concentration in nmol/mg of organ.

Groups	Liver	Kidney	Aorta	Sciatic nerve
HC	0.200 $\pm$ 0.006	0.216 $\pm$ 0.008	0.334 $\pm$ 0.007	0.159 $\pm$ 0.011
NC	0.154 $\pm$ 0.005 ^a	0.139 $\pm$ 0.015 ^b	0.151 $\pm$ 0.012 ^c	0.050 $\pm$ 0.010 ^c
Met	0.212 $\pm$ 0.011 ^y	0.206 $\pm$ 0.012 ^y	0.322 $\pm$ 0.015 ^z	0.162 $\pm$ 0.008 ^z
Da 100	0.206 $\pm$ 0.013 ^y	0.204 $\pm$ 0.007 ^y	0.318 $\pm$ 0.008 ^z	0.161 $\pm$ 0.013 ^z
Da 200	0.194 $\pm$ 0.003 ^x	0.197 $\pm$ 0.011 ^x	0.303 $\pm$ 0.017 ^z	0.148 $\pm$ 0.013 ^z

Each value represents the mean $\pm$ SEM ($n = 5$), *Da*: *D. adscendens*, *HC*: Healthy control, *NC*: Negative control, *Met*: animals receiving metformin, *Da 100* and *Da 200*: animals receiving *Da* extract at the doses of 100 and 200 mg/kg, *GSH*: Reduced glutathione, ^a $p < 0.05$ ^b $p < 0.01$ ^c $p < 0.001$: significant difference from the HC, ^x $p < 0.05$ ^y $p < 0.01$ ^z $p < 0.001$: significant difference from the NC.

3.6.4. Effects on Catalase Activity

Diabetes resulted in a significant ($p < 0.001$) decrease in catalase activity in the organs studied compared to the Healthy control (Table 6). These values were normalized by the different treatments, except in the liver of animals receiving metformin, where catalase activity remains significantly higher than that of the healthy control for 50.8%.

3.6.5. Effects on Superoxide Dismutase Activity

Diabetes significantly decreased the SOD activity in the liver ($p < 0.01$) (41.9%), kidney (89.8%), aorta (91.8%) and sciatic nerve (89.9%) ($p < 0.001$) compared to the HC group (Table 7). The extract led to the normalization of SOD activity in these organs except in the liver where its activity remained significantly higher ($p < 0.01$) than that of the Healthy control.

Table 6. Effect of *D. adscendens* on catalase activity (mM of H₂O₂/min/g organ).

Groups	Liver	Kidney	Aorta	Sciatic nerve
HC	3.451 ± 0.186	1.168 ± 0.060	3.919 ± 0.272	4.775 ± 0.265
NC	0.661 ± 0.186 ^c	0.390 ± 0.064 ^c	1.025 ± 0.162 ^c	0.514 ± 0.088 ^c
Met	5.203 ± 0.190 ^{z a}	1.439 ± 0.087 ^z	4.449 ± 0.315 ^z	5.221 ± 0.428 ^z
Da 100	4.117 ± 0.265 ^z	1.344 ± 0.141 ^z	4.136 ± 0.424 ^z	5.127 ± 0.435 ^z
Da 200	3.542 ± 0.219 ^z	1.202 ± 0.090 ^z	4.029 ± 0.270 ^z	4.817 ± 0.473 ^z

Each value represents the mean ± SEM (n = 5), *Da*: *D. adscendens*, *HC*: Healthy control, *NC*: Negative control, *Met*: animals receiving metformin, *Da 100* and *Da 200*: animals receiving *Da* extract at the doses of 100 and 200 mg/kg, ^a p < 0.05, ^c p < 0.001: significant difference from HC, ^z p < 0.001: significant difference from NC.

Table 7. Effect of *D. adscendens* on SOD activity in SOD unit/mg protein.

Groups	Liver	Kidney	Aorta	Sciatic nerve
HC	6.849 ± 0.272	2.783 ± 0.132	1.018 ± 0.048	2.298 ± 0.234
NC	3.978 ± 0.505 ^b	0.283 ± 0.060 ^c	0.084 ± 0.018 ^c	0.233 ± 0.060 ^c
Met	10.360 ± 0.502 ^{b z}	2.685 ± 0.127 ^z	0.996 ± 0.097 ^z	1.827 ± 0.199 ^z
Da 100	9.960 ± 0.767 ^{b z}	2.583 ± 0.185 ^z	0.911 ± 0.098 ^z	1.730 ± 0.113 ^z
Da 200	9.675 ± 0.293 ^{b z}	2.410 ± 0.272 ^z	0.823 ± 0.042 ^z	1.602 ± 0.075 ^{a z}

Each value represents the mean ± SEM (n = 5), *Da*: *D. adscendens*, *HC*: Healthy control, *NC*: negative control, *Met*: animals receiving metformin, *Da 100* and *Da 200*: animals receiving *Da* extract at the doses of 100 and 200 mg/kg, *SOD*: Superoxide dismutase, ^a p < 0.05 ^b p < 0.01 ^c p < 0.001: significant difference from HC, ^z p < 0.001: significant difference from NC.

3.7. Effects of the Aqueous Extract of *Desmodium adscendens* on Histology Analysis

3.7.1. Effects on the Histoarchitecture of the Liver

The liver of the animals in the HC group had normal architecture with a span-like arrangement of hepatocytes. Diabetes led to disorganization of the hepatocytes, congestion of the central-lobular vein and infiltration of the leukocytes in the hepatocytes. These modifications were little or absent in the liver of animals receiving the aqueous extract of *D. adscendens* (Figure 4).

3.7.2. Effects on the Histoarchitecture of the Kidney

Diabetes has caused mesangial expansion (glomerular and interstitial) and leukocyte infiltration as well as obstruction of

the proximal and distal convoluted tubules. The aqueous extract of *D. adscendens* corrected these renal architecture disorders in a dose-dependent manner (Figure 5).

3.7.3. Effects on the Histoarchitecture of the Aorta

Diabetes led to a thickening of the media (Figure 6), resulting in a significant (p < 0.05) decrease in the intima-to-media ratio in the NC group compared to the HC group (Table 8). The aqueous extract of *D. adscendens* caused a reduction in the thickness of this tunic.

3.7.4. Effects on Adrenal Cortex Histoarchitecture

The adrenal cortex, which has three layers, ensures the production of substances that intervene in the stress response. The induction of diabetes and the various treatments have not affected the relative thickness of these different parts (Figure 7, Table 9).

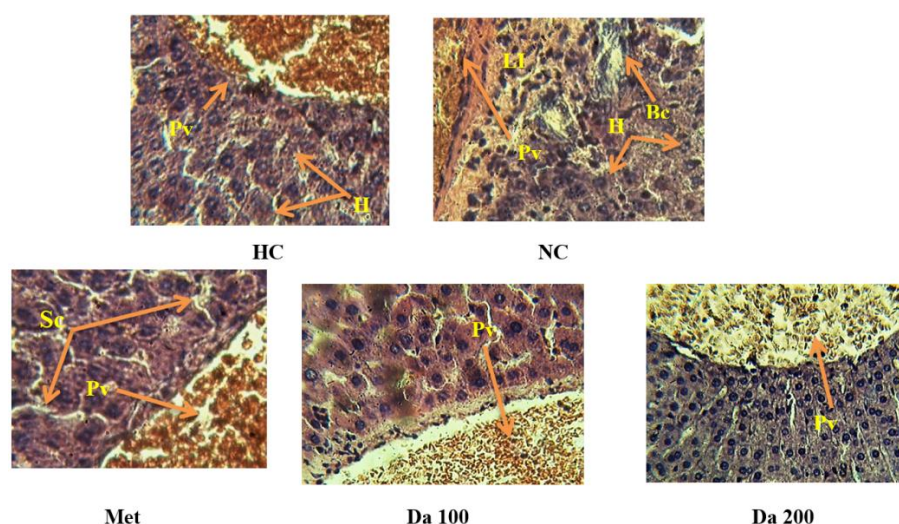


Figure 4. Liver sections of the animals of the different groups (H-E x400).

Da: *D. adscendens*, *HC*: Healthy control, *NC*: negative control, *Met*: animals receiving metformin, *Da 100* and *Da 200*: animals receiving *Da* extract at the doses of 100 and 200 mg/kg; *H-E*: Hematoxylin-Eosin; *Bc*: biliary canaliculus; *LI*: Leukocytes Infiltration; *Sc*: sinusoidal capillary; *Vc*: vascular congestion; *H*: hepatocytes; *Pv*: portal vein.

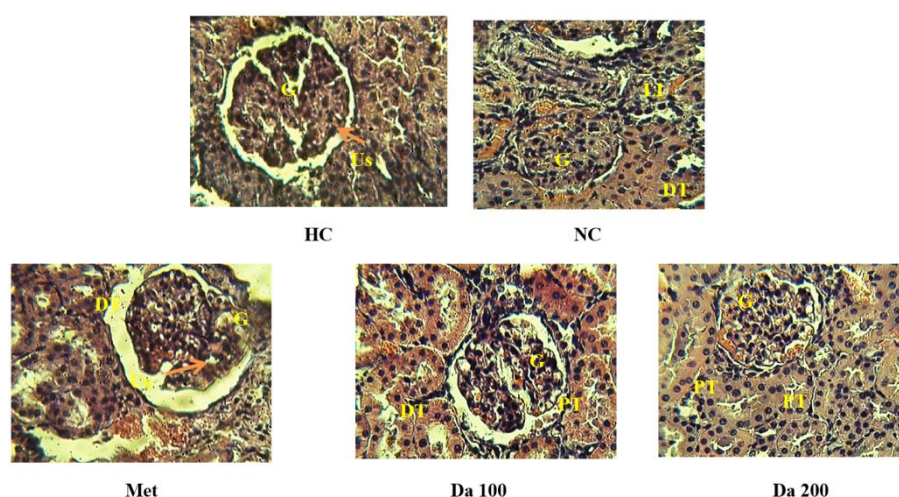


Figure 5. Longitudinal section of the kidney of the rats of the different groups (H-E x400).

Da: *D. adscendens*, *HC*: Healthy control, *NC*: negative control, *Met*: animals receiving metformin, *Da 100* and *Da 200*: animals receiving *Da* extract at the doses of 100 and 200 mg/kg; *DT*: distal tubule; *G*: glomerule; *H-E*: Hematoxylin-Eosin; *LI*: leukocyte infiltration; *PT*: proximal tubule; *Us*: urinary space.

4. Discussion

The study assessed the effects of aqueous extract of *Desmodium adscendens* on diabetes and its complications in Wistar rats made diabetic by prolonged sucrose administration and a single injection of streptozotocin (STZ).

Hyperglycemia is a key indicator of diabetes. The study found that administering sucrose and STZ to rats caused a permanent increase in blood sugar levels in the negative control (NC) group. STZ destroys pancreatic β cells, leading to

hyperglycemia and decreased insulin secretion [30, 31]. Additionally, when combined with a high-calorie diet, STZ increases the rats' susceptibility to significant hyperglycemia and hyperlipidemia, resembling human type 2 diabetes [32]. Moreover, high-fructose consumption, as in our study, leads to insulin resistance and impairs glucose metabolism [15, 33]. The rise in glycaemia, along with weight loss, increased water consumption, and the Oral Glucose Tolerance Test (OGTT) results observed in this model, as described by Djientcheu *et al.* [21], confirmed the onset of diabetes mellitus. It has previously been shown that a hypercaloric diet combined with

low doses of STZ increases the rats' susceptibility to significant hyperglycemia by reducing insulin secretion after pancreatic β -cell destruction, resembling human type 2 diabetes [15, 32].

The aqueous extract of *D. adscendens* has been shown to decrease blood glucose levels in diabetic rats after 28 days of administration. These findings are similar to those obtained with metformin, a commonly used anti-diabetic drug that improves insulin sensitivity in the liver, muscles, and adipose tissue [34]. This extract's hypoglycemic effect may be due to the stimulation of pancreatic islets and the regeneration of pancreatic cells that were partially destroyed by STZ. It could also be the result of an increase in the peripheral use of glu-

cose [21]. *D. adscendens* contains various biomolecules such as alkaloids, saponins, polyphenols and flavonoids which are known for their hypoglycemic activity through the stimulation of the secretion and regeneration of beta-cell islets and the inhibition of carbohydrate digestion and glucose uptake in the intestine. These biomolecules also activate the enzymes responsible for glucose utilization [31]. The findings are consistent with those of Bilanda *et al.* [35], who showed that the hypoglycemic effects of the aqueous extract of *Erythrina senegalensis* DC (Fabaceae) stem bark could be attributed to either an insulin-like effect of the extract or its ability to stimulate the remaining β cells to secrete insulin.

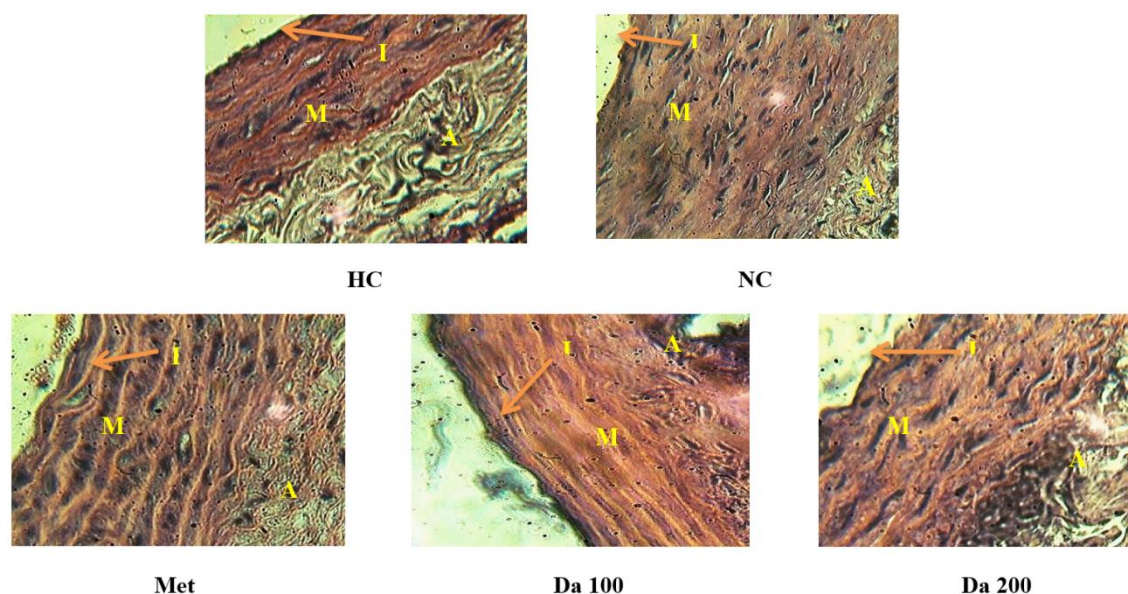


Figure 6. Cross-section of the aorta of the rats of the different groups (H-E x400).

Da: *D. adscendens*, *HC*: Healthy control, *NC*: negative control, *Met*: animals receiving metformin, *Da 100* and *Da 200*: animals receiving *Da* extract at the doses of 100 and 200 mg/kg; *H-E*: Hematoxylin-Eosin; *A*: adventitious; *I*: intima; *M*: media.

Table 8. Histomorphometry of the aorta.

Thickness	HC	NC	Met	Da 100	Da 200
Intima (mm)	0.011 $\pm$ 0.002	0.011 $\pm$ 0.001	0.012 $\pm$ 0.001	0.009 $\pm$ 0.001	0.013 $\pm$ 0.002
Media (mm)	0.256 $\pm$ 0.031	0.601 $\pm$ 0.036	0.290 $\pm$ 0.030	0.195 $\pm$ 0.012	0.303 $\pm$ 0.032
RIM	0.040 $\pm$ 0.003	0.019 $\pm$ 0.002 ^a	0.042 $\pm$ 0.005 ^y	0.047 $\pm$ 0.002 ^z	0.042 $\pm$ 0.004 ^y

Each value represents the average $\pm$ SEM (n = 25), *RIM*: Intima/Media Ratio, *Da*: *D. adscendens*, *HC*: Healthy control, *NC*: negative control, *Met*: animals receiving metformin, *Da 100* and *Da 200*: animals receiving *Da* extract at the doses of 100 and 200 mg/kg, ^ap < 0.05: significant difference from HC, ^yp < 0.01 ^zp < 0.001: significant difference from NC.

The significant reduction in total protein levels exhibited by untreated diabetic animals would be at the origin of the weight loss recorded in the present model and could at least partly explain the physical asthenia associated with the diabetic state

[21, 33]. Furthermore, the increased transaminase and alkaline phosphatase activities in their serum could be the consequence of the release of these liver enzymes due to STZ hepatotoxicity [15]. The reduction in the activity of these

enzymes observed after administration of *D. adscendens* could reflect the hepatoprotective activity of this extract. The flavonoids and polyphenols present in the extract may repair the cell membrane, thereby preserving the structural integrity

of the liver while restoring its function. Moreover, these compounds can scavenge free radicals generated during metabolism in diabetic conditions, as suggested by many studies [6, 8, 9].

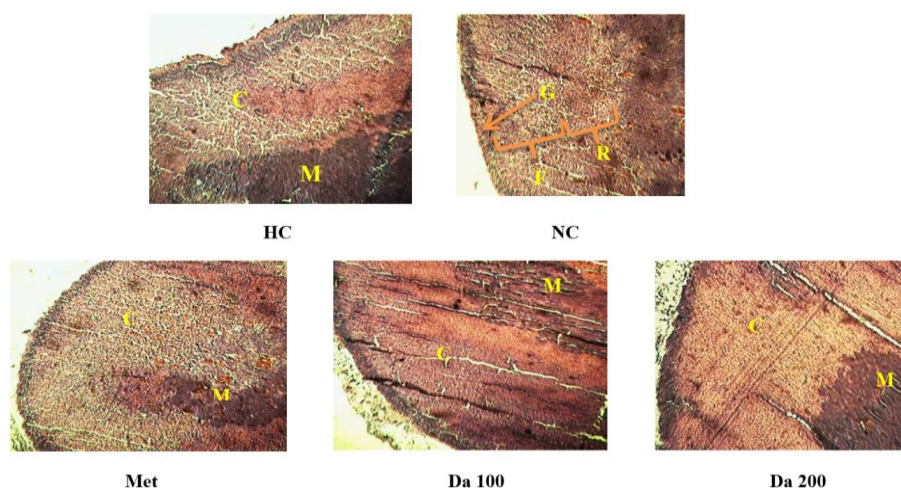


Figure 7. Longitudinal sections of the adrenal gland (H-E, x50).

Da: *D. adscendens*, *HC*: Healthy control, *NC*: negative control, *Met*: animals receiving metformin, *Da 100* and *Da 200*: animals receiving *Da* extract at the doses of 100 and 200 mg/kg; *H-E*: Hematoxylin-Eosin; *C*: adrenal cortex; *F*: fasciculate zone; *G*: glomerular zone; *M*: adrenal medulla; *R*: reticulate zone.

Table 9. Histomorphometry of the adrenal gland.

Thickness	HC	NC	Met	Da 100	Da 200
Fasciculate zone (mm)	0.121 ± 0.011	0.168 ± 0.011	0.125 ± 0.011	0.131 ± 0.013	0.119 ± 0.012
Adrenal cortex (mm)	0.261 ± 0.024	0.327 ± 0.025	0.260 ± 0.019	0.312 ± 0.018	0.276 ± 0.016
Ratio	0.467 ± 0.018	0.524 ± 0.030	0.480 ± 0.009	0.438 ± 0.017	0.435 ± 0.026

Each value represents the mean ± SEM (n = 25), *Da*: *D. adscendens*, *HC*: Healthy control, *NC*: negative control, *Met*: animals receiving metformin, *Da 100* and *Da 200*: animals receiving *Da* extract at the doses of 100 and 200 mg/kg.

On the other hand, the increase in creatinine levels in the NC group is due to a decrease in the kidney's capacity to filter out waste products, which is caused by complications of diabetes [36]. Diabetic kidney disease, in which high creatininaemia is one manifestation, is characterized by a progressive increase in albuminuria and a gradual decline in the glomerular filtration rate and kidney functions [6, 36]. Degradation of kidney functions was also shown with the histopathological changes in the kidneys, as indicated by mesangial expansion as well as obstruction of the proximal and distal convoluted tubules in the NC group. These histological alterations could be the consequences of oxidative stress, which exacerbates progressive glomerular damage, tubular atrophy, and interstitial fibrosis, leading to decreased renal function and renal failure [37, 38]. In diabetic rats treated with *D. adscendens*, the normalization of creatinine clearance

indicates an improvement in renal function or a reduction in the catabolism of creatine and phosphocreatine in muscles [39]. The extracts used in this study were found to improve renal function by reducing oxidative stress, inflammation, and tissue damage, as well as promoting cell proliferation in the kidneys [38].

If untreated, diabetes can result in multiple complications associated with oxidative stress, which can lead to dysfunction in certain organs. These complications primarily affect the cardiovascular and nervous systems, as well as the urinary system and the liver. Various research studies have demonstrated that patients with type 2 diabetes mellitus experience increased production of reactive oxygen species, leading to heightened oxidative damage in the circulation, and have reduced antioxidant defence mechanisms [40].

In this study, it was observed that the NC group had an in-

crease in MDA in the liver, kidney, aorta, and sciatic nerve compared to the healthy control group. This is an indication of altered cell membranes and reduced antioxidant defences [41, 42]. During diabetes, hypoinsulinemia increases the activity of the fatty acyl-coenzyme A oxidase, which initiates the beta-oxidation of fatty acids, leading to the accentuation of lipid peroxidation with MDA production [38, 43], which could lead to the overproduction of free radicals. This process affects the cell membranes' fluidity and decreases the activity of enzymes and the receptors linked to them, including the insulin receptor [44]. The results suggest that *D. adscendens* was able to protect the tissues studied against the production of free radicals and prevent tissue damage caused by oxidative stress due to diabetes. These results are similar to those observed with different plant extracts by many authors [35, 45, 46].

Our research has shown that diabetes causes a significant decrease in SOD and catalase activities, as well as in the concentration of GSH in the organs of untreated diabetic subjects when compared to HC group. These results have been corroborated by many authors who have linked oxidative stress to the depletion of these parameters in animals [33, 35, 45]. Indeed, oxidative stress leads to the inactivation of proteins or enzymes, such as SOD and catalase, and a reduction in these proteins promotes oxidative stress [8, 10]. As seen with metformin, the administration of *D. adscendens* extract to diabetic rats resulted in an increase in SOD and catalase activity. This suggests that the extract, due to its biomolecules, may have reduced the production of oxygen-free radicals and/or enhanced the activity of antioxidant enzymes [16].

At the end of the treatment with *D. adscendens*, the level of tissular GSH was found to be similar to that of HC group. This suggests that the extract of *D. adscendens* was able to enhance GSH regeneration by boosting intracellular NADPH, which helped to restore the cellular redox status [40]. Additionally, the extract contains polyphenolic compounds, which are known for their ability to act as ROS scavengers [35, 47]. This may directly contribute to the reduction in the use of GSH.

Hyperglycemia leads to an increase in ROS, which disrupts crucial metabolic pathways and contributes to diabetic vascular disease [48]. In untreated diabetes, there is an excess production of ROS, which reduces the availability of reserve nitric oxide (NO) in the form of nitrites, a vasodilator [7], as evidenced by our findings. This leads to the proliferation of vascular smooth muscle, resulting in a decrease in the intima/media ratio as observed in the histology of the aorta. Hence, the reduction in nitrite concentration in the aorta of untreated diabetic animals compared to normal indicates endothelial dysfunction [6], which exacerbates vascular smooth muscle cell ageing and the onset of vascular calcification [37] with adverse cardiovascular implications. However, the increase in the concentration of nitrites in the aorta of diabetic animals treated with an aqueous extract of *D. adscendens*, as well as the normalization of the intima/media ratio in this group, is attributed to its antioxidant effect.

Moreover, this outcome could be due to the inhibition of Nicotinamide Adenine Dinucleotide Phosphate (NADPH) oxidase, as suggested by Hayashi *et al.* [49], who obtained similar results with inhibitors of this enzyme.

However, an increase in the nitrite concentration in the liver of the negative control compared to that of the HC group can be an inflammatory sign [50]. During acute inflammation, pro-inflammatory cytokines increase, which stimulate the production of NO and result in an increase in its concentration in the liver, leading to histologic changes such as fibrosis, cirrhosis, or liver disease [10], as observed in our study. If untreated, inflammation becomes chronic, leading to the production of anti-inflammatory cytokines that inhibit NO-synthase. This mechanism may explain the low concentration of nitrites in the kidney of the NC group, which presents some alterations previously described in other studies [6, 48]. Our study shows that the administration of the aqueous extract of *D. adscendens* improved the inflammatory status, suggesting that this plant has anti-inflammatory effects. These results are supported by histological sections of the liver, which demonstrate a disappearance of pro-inflammatory cells in the groups treated with the extract, and a significant reduction in oxidative damage at the renal level. These results may be due to the hypoglycemic, anti-inflammatory and antioxidant effects of the plant.

5. Conclusions

The present study demonstrated that the aqueous extract obtained from the aerial parts of *D. adscendens* can effectively protect rats from metabolic disturbances caused by diabetes induced by sucrose and streptozotocin. These findings suggest that the decrease in blood sugar levels observed in animals treated with the aqueous extract of *D. adscendens* could be attributed to the amelioration of insulin sensitivity and the protection of organs involved in its regulation. However, more research is needed to identify the bioactive molecules and to elucidate the exact mechanism of action of this plant extract.

Abbreviations

Da (100 or 200)	Aqueous Extract of <i>D. adscendens</i> at 100 or 200 mg/kg
GSH	Glutathione
HC	Healthy Control
HDL	High-Density Lipoprotein
LDL	Low-Density Lipoprotein
MDA	Malondialdehyde
MET	Metformin
NC	Negative Control
ROS	Reactive Oxygen Species
SOD	Superoxide Dismutase
STZ	Streptozotocin

WHO

World Health Organization

Acknowledgments

The authors express gratitude to the French association *Pathologie Cytologie Développement* for histological reagents and the traditional healer for the medicinal plant.

Author Contributions

Franck Yvan Djientcheu Deugoue: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Resources, Software, Validation, Writing - original draft, Writing - review & editing

Arnaud Galvani Nekam: Investigation, Resources, Validation, Writing - original draft

Henri Tetang: Investigation, Resources, Validation, Writing - original draft

Lohik Mbolang Nguegan: Formal Analysis, Methodology, Software

Aicha El-Ramadan Malane Nsangou: Data curation, Formal Analysis, Writing - original draft

Madeleine Chantal Ngougoure: Methodology, Writing - review & editing

Mireille Kameni Poumeni: Methodology, Writing - review & editing

Yolande Sandrine Mengue Ngadena: Methodology, Writing - review & editing

Dieudonne Pascal Chuisseu Djamen: Methodology, Writing - review & editing

Paul Desire Dzeufiet Djomeni: Conceptualization, Methodology, Supervision, Validation, Writing - review & editing

Ethical Considerations

We made every effort to ensure that no animals were subjected to unnecessary suffering during the experiment.

Funding

This work is not supported by any external funding.

Data Availability

The data used to support the findings of this study are included in the article. Raw data are available on request from the corresponding author.

Conflicts of Interest

The authors declare no conflicts of interest.

References

- [1] OMS. Diabète, aide mémoire N°312. Genève; 2015.
- [2] Rehman K, Akash MSH. Mechanism of generation of oxidative stress and pathophysiology of type 2 diabetes mellitus: how are they interlinked? *J Cell Biochem.* 2017; 118(11): 3577-85. <https://doi.org/10.1002/jcb.26097>
- [3] Nguenim FT, Esse EC, Dzeufiet PDD, Gounoue RK, Bilanda DC, Kamtchouing P, et al. Oxidised palm oil and sucrose induced hyperglycemia in normal rats: Effects of sclerocarya birrea stem barks aqueous extract. *BMC Complement Altern Med* [Internet]. 2016; 16(47): 1-11. Available from: <http://dx.doi.org/10.1186/s12906-016-1009-0>
- [4] Gandhi J, Dagur G, Warren K, Smith N, Khan SA. Effect of Diabetes Mellitus on Sexual Arousal and Intercourse. *Transl Biomed.* 2016; 7(2): 57-61. <https://doi.org/10.21767/2172-0479.100057>
- [5] IDF. IDF Diabetes Atlas | Global Diabetes Data & Statistics [Internet]. Brussels; 2025 [cited 2025 Sep 12]. Available from: <https://diabetesatlas.org/>
- [6] Charlton A, Garzarella J, Jandeleit-Dahm KAM, Jha JC. Oxidative stress and inflammation in renal and cardiovascular complications of diabetes. *Biology (Basel).* 2021; 10(1): 1-18. <https://doi.org/10.3390/biology10010018>
- [7] Ito F, Sono Y, Ito T. Measurement and clinical significance of lipid peroxidation as a biomarker of oxidative stress: Oxidative stress in diabetes, atherosclerosis, and chronic inflammation. *Antioxidants.* 2019; 8(3). <https://doi.org/10.3390/antiox8030072>
- [8] Burgos-Morón E, Abad-Jiménez Z, de Marañón AM, Iannantuoni F, Irene Escribano-López F, López-Domènech S, et al. Relationship Between Oxidative Stress, ER Stress, and Inflammation in Type 2 Diabetes: The Battle Continues. *J Clin Med.* 2019; 8(9): 1385. <https://doi.org/10.3390/jcm8091385>
- [9] Yaribeygi H, Sathyapalan T, Atkin SL, Sahebkar A. Molecular Mechanisms Linking Oxidative Stress and Diabetes Mellitus. *Oxid Med Cell Longev.* 2020; 2020. <https://doi.org/10.1155/2020/8609213>
- [10] Oguntibeju OO. Type 2 diabetes mellitus, oxidative stress and inflammation: examining the links. *Int J Physiol Pathophysiol Pharmacol.* 2019; 11(3): 45-63.
- [11] Kashiwagi A, Shinozaki K, Nishio Y, Okamura T, Toda N, Kikkawa R. Free radical production in endothelial cells as a pathogenetic factor for vascular dysfunction in the insulin resistance state. *Diabetes Res Clin Pract.* 1999; 45: 199-203. [https://doi.org/10.1016/s0168-8227\(99\)00062-5](https://doi.org/10.1016/s0168-8227(99)00062-5)
- [12] Krippeit-Drews P, Lang F, Hiiussinger D, Drews G. H2O2 induced hyperpolarization of pancreatic B-cells. *Pflugers Arch J Physiol.* 1994; 426(6): 552-4. <https://doi.org/10.1007/BF00378534>
- [13] Rudich A, Tirosh A, Potashnik R, Hemi R, Kanety H, Bashan N. Prolonged Oxidative Stress Impairs Insulin-Induced GLUT4 Translocation in 3T3-L1 Adipocytes. *Diabetes.* 1998; 47(10): 1562-9. <https://doi.org/10.2337/diabetes.47.10.1562>

- [14] Nagy C, Einwallner E. Study of in vivo glucose metabolism in high-fat diet-fed mice using Oral Glucose Tolerance Test (OGTT) and Insulin Tolerance Test (ITT). *J Vis Exp [Internet]*. 2018; 131(e56672): 1-12. Available from: <https://doi.org/10.3791/56672>
- [15] Sahin N, Orhan C, Erten F, Tuzcu M, Deeh PBD, Ozercan IH, et al. Effects of allyl isothiocyanate on oxidative stress status in high - fat diet streptozotocin - induced type 2 diabetes mellitus in rats. *J Biochem Mol Toxicol*. 2019; 7(33): 9. <https://doi.org/10.1002/jbt.22328>
- [16] Yedjou CG, Grigsby J, Mbemi A, Nelson D, Mildort B, Latinwo L, et al. The Management of Diabetes Mellitus Using Medicinal Plants and Vitamins. *Int J Mol Sci*. 2023; 24(10)(9085): 1-14. <https://doi.org/10.3390/ijms24109085>
- [17] Rachid AP, Moncada M, De Mesquita MF, Brito J, Bernardo MA, Silva ML. Effect of aqueous cinnamon extract on the postprandial glycemia levels in patients with Type 2 Diabetes Mellitus: A randomized controlled trial. *Nutrients*. 2022; 14(1576): 1-10. <https://doi.org/10.3390/nu14081576>
- [18] WHO. Traditional Medicine Strategy 2002-2005. Geneva; 2005.
- [19] Miague N. Etude phytochimique et évaluation de l'activité hépatoprotectrice d'une formulation galénique à base de *Desmodium adscendens* (Fabacées) récoltés avant et après floraison. Université des Montagnes; 2010.
- [20] Muanda FN. Identification de polyphénols, évaluation de leur activité antioxydante et étude de leurs propriétés biologiques. Université Paul Verlaine-Metz- France; 2010.
- [21] Djientcheu FYD, Nekam AG, Tetang H, Malane AERN. Effects of aqueous extract of *Desmodium adscendens* aerial parts on insulin and glycemic reactivity and weight development in type 2 diabetic rats. *Pap Med Sci*. 2023; 3(e001): 1-11.
- [22] Ayoola GA, Coker HAB, Adesegun SA, Adepoju-bello AA, Obaweya K, Ezennia EC, et al. Phytochemical Screening and Antioxidant Activities of Some Selected Medicinal Plants Used for Malaria Therapy in Southwestern Nigeria. *Trop J Pharm Res*. 2008; 7(3): 1019-24. <https://doi.org/10.4314/tjpr.v7i3.14686>
- [23] ADA. 2. Diagnosis and Classification of Diabetes: Standards of Care in Diabetes-2025. *Diabetes Care [Internet]*. 2025 Jan 1 [cited 2025 Sep 12]; 48(1 Suppl 1): S27-49. Available from: <https://pubmed.ncbi.nlm.nih.gov/39651986/>
- [24] Dobišová M, Frohlich J. The plasma parameter log (TG/HDL-C) as an atherogenic index: correlation with lipoprotein particle size and esterification rate in apoB-lipoprotein-depleted plasma (FER(HDL)). *Clin Biochem*. 2001; 34(7): 583-8. [https://doi.org/10.1016/S0009-9120\(01\)00263-6](https://doi.org/10.1016/S0009-9120(01)00263-6)
- [25] Smith A, Bruton J. Color Atlas of Histological Staining Technique. London: Wolfe Medical; 1977. 192 p. <https://doi.org/10.1136/pgmj.54.630.292-b>
- [26] Sinha AK. Colorimetric assay of catalase. *Anal Biochem*. 1972; 47(2): 389-94. [https://doi.org/10.1016/0003-2697\(72\)90132-7](https://doi.org/10.1016/0003-2697(72)90132-7)
- [27] Misra HP, Fridovich I. Determination of superoxide dismutase and glutathione peroxidase activities in blood of healthy pediatric subjects. Yale University Press, New Haven. [https://doi.org/10.1016/S0009-8981\(02\)00163-8](https://doi.org/10.1016/S0009-8981(02)00163-8)
- [28] Slack PT. Analytical methods manual [Internet]. 2nd ed. Leatherhead Food Research Association, editor. Leatherhead, England: British Food Manufacturing Industries Research Association; 1987 [cited 2022 Oct 21]. Available from: <https://www.worldcat.org/fr/title/analytical-methods-manual/olc/152415187>
- [29] Wilbur K, Bernhein F, Shapiro O. Determination of lipid peroxidation. *Arch Biochem Biophys*. 1949; 24: 3959-64.
- [30] Murata M, Takahashi A, Saito I, Kawanishi S. Site-specific DNA Methylation and Apoptosis: Induction by Diabetogenic Streptozotocin. *Biochem Pharmacol*. 1999; 57(8): 881-7. [https://doi.org/10.1016/S0006-2952\(98\)00370-0](https://doi.org/10.1016/S0006-2952(98)00370-0)
- [31] Kolefer K, Miaffo D, Ponka R. Evaluation of Antidiabetic Properties of the Leaves Extract of *Ficus vallis-choudae* Delile in a Model of Type 2 Diabetes Induced by High-Fat Diet and Streptozotocin. *Sci World J*. 2021; 2021(1502230): 1-10. <https://doi.org/10.1155/2021/1502230>
- [32] Bansal P, Paul P, Mudgal J, G. Nayak P, Thomas Pannakal S, Priyadarsini KI, et al. Antidiabetic, antihyperlipidemic and antioxidant effects of the flavonoid rich fraction of *Pilea microphylla* (L.) in high fat diet/streptozotocin-induced diabetes in mice. *Exp Toxicol Pathol [Internet]*. 2012; 64(6): 651-8. Available from: <http://dx.doi.org/10.1016/j.etp.2010.12.009>
- [33] Djientcheu JPT, Nguenim FT, Gounoue RK, Fifen RN, Dzeufiet PDD, Dimo T. The aqueous extract of *Sclerocarya birrea*, *Nauclea latifolia*, and *Piper longum* mixture protects striatal neurons and movement- associated functionalities in a rat model of diabetes-induced locomotion dysfunction. *Evidence-Based Complement Altern Med*. 2023; 2023(Article ID 7865919): 1-11. <https://doi.org/10.1155/2023/7865919>
- [34] Nkono BLNY, Sokeng SD, Dzeufiet PDD, Kamtchouing P. Antihyperglycemic and antioxydant properties of *Alstonia boonei* De Wild. (Apocynaceae) stem bark aqueous extract in dexamethasone-induced hyperglycemic rats. *Int J Diabetes Res*. 2014; 3(3): 27-35. <https://doi.org/10.5923/j.diabetes.20140303.01>
- [35] Bilanda DC, Bidingha R à G, Djomeni Dzeufiet PD, Fouda YB, Ngapout RF, Tcheutchoua Y, et al. Antihypertensive and antidiabetic activities of *Erythrina senegalensis* DC (Fabaceae) stem bark aqueous extract on diabetic hypertensive rats. *J Ethnopharmacol [Internet]*. 2019; 246(112200): 1-21. Available from: <https://doi.org/10.1016/j.jep.2019.112200>
- [36] Yan LJ. The Nicotinamide/Streptozotocin Rodent Model of Type 2 Diabetes: Renal Pathophysiology and Redox Imbalance Features. *Biomolecules*. 2022; 12 (9)(1225): 1-16. <https://doi.org/10.3390/biom12091225>
- [37] Jin Q, Liu T, Qiao Y, Liu D, Yang L, Mao H, et al. Oxidative stress and inflammation in diabetic nephropathy: role of polyphenols. *Front Immunol*. 2023; 14(1185317): 1-17. <https://doi.org/10.3389/fimmu.2023.1185317>

- [38] Roosdiana A, Permata FS, Fitriani RI, Umam K, Safitri A. *Ruellia tuberosa* L. Extract Improves Histopathology and Lowers Malondialdehyde Levels and TNF Alpha Expression in the Kidney of Streptozotocin-Induced Diabetic Rats. *Vet Med Int*. 2020; 2020(8812758): 1-7. <https://doi.org/10.1155/2020/8812758>
- [39] Palsamy P, Subramanian S. Resveratrol, a natural phytoalexin, normalizes hyperglycemia in streptozotocin-nicotinamide induced experimental diabetic rats. *Biomed Pharmacother* [Internet]. 2008; 62(9): 598-605. Available from: <https://dx.doi.org/10.1016/j.biopha.2008.06.037>
- [40] Tangvarasittichai S. Oxidative stress, insulin resistance, dyslipidemia and type 2 diabetes mellitus. *World J Diabetes*. 2015; 6(3): 456-80. <https://doi.org/10.4239/wjd.v6.i3.456>
- [41] Gupta M, Mazumder UK, Kumar TS, Gomathi P, Kumar RS. Antioxidant and hepatoprotective effects of *Bauhinia racemosa* against paracetamol and carbon tetrachloride-induced liver damage in rats. *Iran J Pharmacol*. 2004; 3(1): 12-20. <https://doi.org/0000-0000/04/31-12-20>
- [42] Osman M, Fayed S, Mahmoud GI, Romeilah R. Protective Effects of Chitosan, Ascorbic Acid and *Gymnema Sylvestre* Against Hypercholesterolemia in Male Rats. *Aust J Basic Appl Sci*. 2010; 4(1): 89-98. Available from: <https://www.cabdirect.org/cabdirect/abstract/20103359516>
- [43] Horie S, Ishii H, Suga T. Changes in Fatty Acid Oxidation in the Peroxisomal Diabetic Rat Liver. *J Biochem*. 1981; 90(6): 1691-6. <https://doi.org/10.1093/oxfordjournals.jbchem.a133645>
- [44] Rahimi R, Nikfar S, Larijani B, Abdollahi M. A review on the role of antioxidants in the management of diabetes and its complications. *Biomed Pharmacother*. 2005; 59: 365-73. <https://doi.org/10.1016/j.biopha.2005.07.002>
- [45] Dzeufiet DP, D'ésir é Mogueo A, Bilanda DC, Aboubakar B, farouck O, T'édong L, Dimo T, et al. Antihypertensive potential of the aqueous extract which combine leaf of *Persea americana* Mill. (Lauraceae), stems and leaf of *Cymbopogon citratus* (D. C) Stapf. (Poaceae), fruits of *Citrus medica* L. (Rutaceae) as well as honey in ethanol and sucrose exper. *BMC Complement Altern Med*. 2014; 14(507): 1-12. <https://doi.org/10.1186/1472-6882-14-507>
- [46] Beyssiri D, Dongmo F, Souady ID, Mahamat AH, Ngimout KN, Dongmo SS, et al. Antidiabetic and Antioxidant Effect of Ethanolic Extract of Propolis from Meiganga (Cameroon) on Type 2 Diabetes in Rats. *Int J Diabetes Endocrinol*. 2024; 9(1): 1-12. <https://doi.org/10.11648/j.ijde.20240901.11>
- [47] Atsamo A, NeneBi A, Kouakou L, Fofi C, Nyadjeu P, Watcho P, et al. Cardiovascular and Antioxidant Effects of the Methanol Extract From the Stem Bark of *Erythrina Senegalensis* DC (Fabaceae). *J Physiol Pharmacol Adv*. 2013; 3(4): 110-20. <https://doi.org/10.5455/jppa.20130430124448>
- [48] Pickering RJ, Rosado CJ, Sharma A, Buksh S, Tate M, de Haan JB. Recent novel approaches to limit oxidative stress and inflammation in diabetic complications. *Clin Transl Immunol*. 2018; 7(4): 1-20. <https://doi.org/10.1002/cti2.1016>
- [49] Hayashi T, Juliet P, Kano-Hayashi H, Tsunekawa T, Dingqunfang D, Sumi D, et al. NADPH oxidase inhibitor, apocynin restores the impaired endothelial-dependent and independent responses and scavengers superoxide anion in rats with type 2 diabetes complicated by NO dysfunction. *Diabetes Obes Metab*. 2005; 7: 334-43. <https://doi.org/10.1111/j.1463-1326.2004.00393.x>
- [50] Thom SR, Bhople VM, Mancini DJ, Milovanova TN. Actin S-Nitrosylation Inhibits Neutrophil $\beta 2$ Integrin Function. *J Biol Chem*. 2008; 283(16): 10822-34. <https://doi.org/10.1074/jbc.M709200200>