

Original Article:

Histomorphology of the Beta-Cells and Phytochemical Evaluation of Ethanolic Leaf Extract of Africa Star Apple - *Chrysophyllum albidum* (Sapotaceae)

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Abstract:

Objective: Studies have recognized the numerous health benefits of *Chrysophyllum albidum*. This study examine the phytochemical evaluation of ethanolic leaf extract of *C. albidum* and its histological effects on the beta-cells of streptozotocin-induced diabetic rats. **Method:** Forty-two Sprague-Dawley rats (170-200 g) were divided into six (n=7) groups. Groups 1 and 2 were given 10 mL of normal saline; group 3 was given 2 mg/kg of glibenclamide; and groups 4, 5, and 6 were given 125, 250, and 500 mg/kg/day of *C. albidum* ethanolic leaf extract, respectively. Except for group 1, animals in groups 2-6 were injected intraperitoneally with 50 mg/kg streptozotocin after 14 days of oral treatment with normal saline, glibenclamide, and extract. For the next 14 days, rats were given normal saline, glibenclamide, and extract. The rats were fasted overnight before sacrifice on day 14; the pancreas was removed under diethyl ether anaesthesia and prepared for histological examination using a modified aldehyde fuchsin staining technique. Standard procedures were used for phytochemical evaluation and proximate analysis. **Results:** It was observed histological that the pancreatic tissues revealed cellular regeneration of the damage beta cells at a doses of 250 and 500 mg/kg/day. Phytochemical screening revealed the following; anthocyanin, cardiac glycosides, alkaloids, flavonoids, phenols, terpenoids, reducing sugar, and tannins while proximate analysis confirmed that the leaf contained 4.83% moisture, 39.59% crude fibre, 3.35% ash, 2.35% crude fats, 3.21% crude proteins and 46.71% carbohydrate. **Conclusion:** The results shows that *C. albidum* may possess a strong pharmacological activity owing to its rich phyto-constituents. This may have mediated its antidiabetic action by pancreatic beta cells regeneration. Hence, *C. albidum* could be a potential drug precursor for management of diabetes.

Keywords: *Chrysophyllum albidum*; Diabetes mellitus; Beta-cells; Leaf; Phytochemicals

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Introduction:

The advantage of plants with therapeutic benefits in developed societies has been linked directly to the extraction and manufacture of different drugs from these plants; thus, insight of the biologically active compounds present in plants has been used for medicinal reasons, explaining its use traditionally

in folkloric remedies^{1, 2}. Because of the synergistic effects of crude extract from herbal medicines, it is assumed that extract has a more beneficial effect³. Herbal products are becoming more popular as a result of the difficulties associated with the affordability, efficacy, and accessibility of synthetic drugs^{4, 5}.

Most drugs are currently beneficial in treating early-

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onset of diabetes complications; notwithstanding, severe late-onset complications are reported in a significant number of diabetic patients⁶. The antioxidant and antidiabetic properties of plant extracts have piqued the attention of researchers due to the possibility of replacing synthetic antidiabetics and antioxidants with natural ones. The physiopathology of diabetes, preventing beta cell degeneration, and inducing islet restoration are all key steps in trying to treat diabetes mellitus. Some anti-diabetic phytochemicals have been shown to protect and regenerate pancreatic beta cells⁷.

Phytochemicals have long been known to be an effective source of potential therapeutic agents for a variety of health issues, and research findings have revealed that phytotherapy may be used to manage diabetes^{8,9}. Phytochemicals exert their anti-diabetic effects through a variety of mechanisms, including lowering gastrointestinal glucose absorption, inhibiting liver glucose production, increasing liver glucose uptake, improving beta cell insulin secretion, and allowing pancreatic tissue to regenerate^{10,11}. The desire to procure and use medicinal herbs is growing due to their low toxicity, low cost, and pharmacological potency when compared with synthetic drugs that can be mixed with other substances¹²

Chrysophyllum albidum (Sapotaceae) also called Africa star apple, have been widely recognized in Nigeria to have ethno medicinal uses and are thought to exhibit a variety of therapeutic properties such as antioxidant effect¹³, antihyperglycemic properties^{14,15,13,16}, antihyperlipidaemic effect¹³, and for treating gastrointestinal disorders such as stomach-ache, diarrhoea, and indigestion^{17,18}. Antibacterial¹⁹, antimicrobial²⁰, antiplatelet properties¹⁴, antispermatogenic²¹, treatment of malaria, elevated blood pressure, and anaemia^{22,23}. It is also effective in preventing a threatened miscarriage²⁴, and the leaves are used to treat cough²³. It is also employed to make a soothing ointment or moisturizer for treating dry skin, skin eruptions, and skin itches, as well as to make herbal medicines that are applied to wounds, cuts, sprains, and bruises to promote quick healing²⁵. *C. albidum* leaves are thought to have medico-magical properties that could bring patients back from the brink of death²³. The leaf contains a high concentration of bioactive compounds in the form of secondary metabolites²⁶. As a result, the study concentrated on the phytochemical potential and nutritional benefits of *Chrysophyllum albidum*

leaf on the histomorphology of beta cells.

Materials and Method:

Preparation of *C. albidum* leaves extract

Chrysophyllum albidum leaves were harvested on September 5, 2015 in Elele, Rivers State. The plant was identified and authenticated by Mr Oyebanji O.O of the Department of Botany of the University of Lagos. The specimen was deposited in the herbarium with a voucher number - LUH 7458. One kilograms of powdered leaves was macerated in 5 L of absolute ethanol in a glass jar for four days at room temperature. Using Whatman no. 1 filter paper, the collected ethanolic extract was filtered and concentrated at 50°C using rotary evaporator (BUCHI R-215 Switzerland). It was further dried using oven at 40°C, the dried extract was found to be 84 g was kept in a sterilized glass universal bottle and preserved in a refrigerator at 4°C until when needed¹⁴.

Experimental animals

Forty two adult Sprague Dawley rats, weighing 170-200 g of both sexes were procured from National Institute of Medical Research (NIMR) Yaba, Lagos. The rats were housed in steel mesh cages in the Department of Anatomy animal house, University of Lagos and maintained for two week acclimatization period on commercial rat chow and water *ad libitum*. Randomly rats were distributed into six of seven rats. Group I (normal control, received 10 ml/kg BW of normal saline): Group 2 (diabetic control, 10 ml/kg BW of normal saline): Group 3 (diabetic test group, 2 mg/kg BW of glibenclamide): Group 4 (diabetic test group, 125 mg/kg BW of *C. albidum*): Group 5 (diabetic test group, 250 mg/kg BW of *C. albidum*): Group 6 (diabetic test group, 500 mg/kg BW of *C. albidum*). The normal saline, glibenclamide and extract was administered once per day by gastric intubation for 2 weeks. After induction of diabetes, confirmation of diabetes was done. Furthermore, the administration of the normal saline, glibenclamide and extract continued for 2 more weeks.

Induction of Experimental Diabetes

Diabetes was induced in groups 2, 3, 4, 5, and 6 animals by single injection of 50 mg/kg streptozotocin (STZ) (Sigma, St. Louis, MO, USA) given intraperitoneal, which was dissolved using cold citrate buffer (0.1 M, pH 4.5) to overnight fasted rats. Three days later diabetes was confirmed using Accu-Check Active® blood glucose monitoring

system (Roche Diagnostics, Mannheim, Germany) glucometer. Animals with fasting blood glucose levels >11 mmol/L were regarded to be diabetic²⁷ and included in the study.

Collection of Samples

After an overnight fast, animals were euthanized under diethyl ether anaesthesia and dissected. Pancreatic tissues were carefully excised, rinsed in ice-cold normal saline and preserved in a fixative (10% formaldehyde). The tissues were processed histologically and modified aldehyde fuchsin technique for staining was performed to highlight beta cells²⁸.

Phytochemical Analysis

Qualitative and quantitative phytochemical analyses of the leaf extract of *C. albidum* were performed using standard phytochemical methods as described^{29, 30, 31} except stated.

Test for Tannins

Dried powdered extract sample of 0.5 g was boiled in 20 ml of water using a test tube and filtered. Using a dropper, 0.1% ferric chloride were added. A greenish or blue-black precipitate colour was observed; indicating that tannins was present.

Test for Alkaloids

Powdered material of the extract of 0.5 g was stirred in 5 ml of 1% aqueous hydrochloric acid (HCl) using a water bath that was maintained at (60°C) for a period of 15 minutes and filtered. Drops of Dragendorff's reagent was added to 1 ml of the filtrate using a dropper. Orange-red precipitates were formed indicating that alkaloids was present.

Test for flavonoids

The powdered extract of 1 g was heated with 10 ml of ethyl acetate using steam bath for 3 minutes, it was filtered and allowed to cool. Thereafter, the mixture was filtered. Then 1 ml of dilute ammonia solution was added into 4 ml of the filtrate. The mixture was shaken to produce yellow colouration, indicating that flavonoids was present.

Test for Phenols

To the measured 2 ml of extracts, drops of 10 % lead acetate solution was added. This resulted in white precipitate formation, which indicates that phenols was present.

Test for anthocyanin

Adding 2 ml of extract with 2 ml of 2 N (two normal) solution of hydrochloric acid (HCl). The production of pink-red colour which turns purplish blue when ammonia is added indicates that anthocyanin is present.

Test for Saponins

About 2 g of powdered extract sample was boiled in 20 ml of distilled water using a water bath and filtered. Furthermore, the filtrate of 10 ml was added into distilled water of 5 ml and shaken intensely and observed for a consistent froth formation. Three drops of olive oil was mixed with the frothing and shaken intensely again. Formation of emulsion indicates that saponin was present.

Test for terpenoids

About 5 ml of extract was separately shaken with 2 ml of chloroform. This was followed by pouring 3 ml of concentrated H₂SO₄ by the side of the tube. The present of reddish brown colour of the interface showed that terpenoids is available.

Test for cardiac glycosides

From the extract, 0.5 g was taken and added into distilled water of 5 ml. Thereafter glacial acetic acid of 2 ml which contains a little drops of FeCl₃ was poured to it. Concentrated H₂SO₄ of 1 ml was added by the side of the tube. The production of brownish ring at the interface showed that cardiac glycoside was present.

Test for Carbohydrates

Benedict's reagent of 5 drops was added to 2 ml of the leaf extract in a tube. Therefore, it was kept on a hot plate for a total of 5 minutes. Carbohydrates was showed to be present by the production of brick red precipitate.

Test for Resins

Acetic Anhydride of 2 ml and concentrated H₂SO₄ of few drops were added to the leaf extracts. Formation of the violet colour indicates that resins is present.

Test for reducing sugar

Fehling's solution of 5 ml was mixed with the extract of 5 ml and then heated for a period of 5 minutes using water bath. Brick red precipitate was formed showing that reducing sugar is present.

Quantitative determination of phytochemical constituents

Determination of tannin

The extract of 1 g was macerated using 50 ml of

ethanol and filtered. The filtrate of 5 ml was added 0.3 ml of 0.1N ferric chloride in 0.1N HCl and 0.3 ml of 0.0008 M of potassium ferricyanide and at 720 nm the absorbance was read.

Determination of alkaloid content

The extract sample of 5 g was measured into 250 ml beaker. Thereafter 200 ml of 10 percent acetic acid in ethanol was added. For a period of 4 hours, the mixture was covered and, also allowed to stand. Thereafter, the mixture was filtered and was concentrated using a water bath until it reached the initial volume of one-quarter. Precipitation reached its end when few drops of concentrated ammonium hydroxide were added to the extract. The solution was kept standing for it to settle, the precipitation was gathered together and washed using (2 M) dilute ammonium hydroxide and it was filtered. Alkaloid was the residue that was available, it was dried and weighed.

Determination of flavonoid content

Extract sample of 1 g was macerated using 20 ml of ethyl acetate for 5 min and filtered. Added to the filtrate of 5 ml was dilute ammonia of 5 ml. This mixture was shaken for 5 min. The upper layer of the mixture was collected and at 490 nm the absorbance was read.

Determination of total phenolic content

The extract sample of 1 g was macerated using 20 ml of 80% ethanol and then filtered. Taken 5 ml from the filtrate, this was added to 0.5 ml of folin-ciocalteu reagent and left to react for 30 minutes. To the mixture was added 2 ml of 20% sodium carbonate and at 650 nm the absorbance was measured.

Determination of anthocyanin content

The dried extract weighing 10 g was added into 5 ml of methanol acidified with trifluoroacetic acid 0.1 % (v/v). Aliquots of 10 ml of the extracts were put into a glass tube and adjusted to a volume of 3 ml with methanol acidified with trifluoroacetic acid (TFA) and at 530 nm the absorbance was measured using a Jenway 6705 UV/VIS spectrophotometer against the blank sample containing the mixture methanol/TFA 0.1 % without the sample extract, TAC was estimated as cyanidin 3-O-glucoside at 530 nm using a molar extinction coefficient of $26900 \text{ L/mol}^{-1} \text{ cm}^{-1}$ and molar mass (449.2 g/mol) and was expressed as mg cyanidin 3-O-glucoside (mg Cya3G)/g³².

Determination of terpenoids content

The extract of 1 g was macerated with ethanol

of 50 ml and filtered; 2.5 ml of 5 % aqueous phosphomolybdic acid was poured into 2.5 ml of the filtrate. After which 2.5 ml of the concentrated H_2SO_4 was gradually poured into the mixture. The mixture was kept upright for 30 minutes and to the mixture, ethanol was added into it, to make it up to 12.5 ml. The absorbance reading was recorded at 700 nm.

Determination of cardiac glycoside content

The extract sample of 1 g was macerated with distilled water of 50 ml and filtered. To 1 ml of the filtrate, alkaline picrate solution of 4 ml was added. The mixture was allowed to boil for 5 min and left to cool. The absorbance reading was recorded at 490 nm.

Test for reducing sugar content

Extract sample of 1 g was macerated using distilled water of 20 ml and it was filtered. After which alkaline copper reagent of 1 ml was poured into 1 ml of the filtrate. The mixture was boiled for a period of 5 minutes and kept to cool. Furthermore, 1 ml of phosphomolybdic acid reagent was diluted with 2 ml of distilled water. This was poured to the mixture and the absorbance was recorded at 420 nm.

Determination of proximate composition of leaf of *C. albidum*

These were determined in triplicate using the Association of Official Analytical Chemists methods³³. The crude fat, moisture content, crude fibre, crude protein, and ash were examined. The net difference between the other nutrients and the total percentage composition was used to calculate carbohydrate content.

Determination of moisture content of *C. albidum* leaf

Powdered leaf samples of *C. albidum* were weighed and oven dried to constant weight for 24 hours at 105°C. The dried leaf was then cooled in a desiccator and weight was reweighed. The change in the sample weight was considered as the sample moisture content and expressed to be percentage of the initial weight. The percentage moisture content was calculated using the formula:

$$\text{Percentage moisture} = \frac{W1 - W2}{\text{Weight of sample before drying}} \times 100$$

Where:

W1 = initial weight of crucible + sample

W2 = final weight of crucible + sample

Proximate constituents of moisture

The extract of 2.0 g was put in a petri-dish and dried using an oven at 105 °C to a constant weight.

Determination of lipid in the leaf of *C. albidum*

Exactly 2 g each of leaf of *C. albidum* was weighed and wrapped in a Whatman's filter paper and was firmly tied with a string and placed into a Soxhlet apparatus. The lipid content was then extracted using 250 ml of mixed chloroform and methanol (2:1) put in a round bottomed flask for 8 hours. The decrease in weight of the filter paper plus the string and the increase in weight of extraction in the bottomed flask were noted as the lipid content of the sample. This was then expressed as the initial weight.

The lipid content was calculation as follows:

$$\text{Percentage crude lipid} = \frac{\text{Weight of oil}}{\text{Weight of sample}} \times 100$$

Proximate constituents of crude fats

For the fat extraction, in a filter paper was place 10 g of the extract, rapped and inserted in the soxhlet thimble and fat extraction was done using N-Hexane in 250 ml soxhlet extractor for 2 and half hours.

Determination of crude protein of leaf of *C. albidum*

A quantity of 0.1g leaf powdered samples was enclosed in a Whatman's filter paper number 1, before introduction into a Kjeldahl's apparatus. 10 ml of concentrated H₂SO₄ and 0.5g of a catalyst mixture, Disodium Sulphate (Na₂SO₄), Copper II Sulphate (CuSO₄), Selenium Dioxide (SeO₂) in a proportion of 10:5:1 were added, five pieces of anti-bumping granules were also added. Hence, the digestion flasks were put into the digestion chamber for 2 hours and carefully observed for a change of colour to light green. Digested sample was left to cool and it was diluted using 60 ml distilled water, this was later reconstituted to 100 ml in a volumetric flask by adding distilled water. To 10 ml portion of the diluted solution, 10 ml 5% NaOH was added. Thereafter, solution was introduced into Markham distillation apparatus; it was allowed to distil into 10 ml 2% Boric acid (H₃BO₃) containing five drops of bromocresol green/methyl red indicator to collect exactly 73 ml of the distillate. The collected distillate was then titrated with standard 0.01N HCl³⁴. Therefore to compute the percentage crude protein for the leaf, the formula of was used.

$$\text{Percentage crude protein} = \frac{(a-b) \times 0.01 \times 0.014}{c/d \times e \times 100}$$

Where:

a = Titre value of the digested sample

b = Titre value of the blank sample

c = Volume to which the digested sample was made

d = Volume of NaOH used for distillation

e = weight of the sample

Proximate constituents of crude proteins of the leaf of *C. albidum*

The digested of the extract was done using an acid, the released nitrogen was expressed by suitable titration technique. The protein present was calculated from the nitrogen concentration of the extract. To change measured nitrogen concentration to a protein concentration, a conversion factor of 6.25 virtually equal to 0.16 g nitrogen per gram of protein (F) was employed³².

Determination of crude fibre of the leaf *C. albidum*

A weight of 2 g of the leaf of *C. albidum* was placed into a 250 ml quick fit flask. Exactly 2ml of 1.25% H₂SO₄, five drops of octanol and anti-bumping granules (5 pieces) were put together with the leaf sample and refluxed for a period of 30 minutes before filtering using a Whatman's filter paper (No. 1). The residue obtained from the sample was refluxed in 1.25% NaOH base for 30 minutes, filtered and oven dried at 100 °C for 12 hours. This was then weighed, transferred into a crucible which was then burned to ashes in a furnace at 600 °C over a period of 24 hours. The ashes was weighed. Hence, the difference between the weights of crucible and sample of the leaf plus the crucible and ash was noted as the crude fibre content.

$$\text{Fibre content} = \text{weight of crucible} + \text{sample} - \text{weight of crucible} + \text{ash}$$

Proximate constituents of crude fibre

This was ascertained by decomposition of starch and proteins with dilute acid, while fatty material with dilute base, and then filtration and ignition in the muffle furnace at 550 °C.

Determination of ash content of the leaf of *C. albidum*

The pulverized leaf of *C. albidum* was weighed and placed into a pre-dried and weighed crucible. This was then introduced into a Muffle furnace and heated at 600 °C for two days, then cooled in

a moisture remover (desiccator) before re-weighing.

Percentage of ash content = $\frac{\text{Weight of ash}}{\text{Weight of sample}} \times 100$

Proximate constituents of ash

Briefly 2 g of the leaf extract was put into a platinum crucible which was subjected to furnace and was maintained at 550 °C until a constant final weight was achieved.

Proximate constituents of carbohydrate

Total carbohydrate was determined by difference [100 – (Protein + Crude fibre + Moisture + Fats and oil + ash)]³³.

Statistical analysis

All data obtained were analysed with graph pad prism software, version 5.0. The result were expressed as mean ± standard deviation (SD). Differences between mean were determined using one way analysis of variance followed by Bonferroni post-test. The level of significant was set at $p < 0.05$.

Ethical clearance:

The principles of animal care were followed by the authors. All experiments were carefully, critically looked into and confirmed by the College of Medicine University of Lagos Health Research Ethics Committee (CMUL/HREC/05/16/011).

Result:

The study revealed phytochemicals such as tannins, anthocyanin, flavonoids, alkaloids, cardiac glycosides, terpenoids, total phenol, and reducing sugars. Furthermore, the qualitative phytochemical estimation of the leaf of *C. albidum* showed that total phenol was high (27.79 ± 0.31 mg/100 g) followed by anthocyanin (24.55 ± 0.29 mg/100 g), terpenoids (21.15 ± 0.57 mg/100 g), alkaloids (20.44 ± 1.77 mg/100 g), flavonoids (19.99 ± 0.37 mg/100 g), cardiac glycosides (15.73 ± 0.09 mg/100 g), reducing sugar (15.69 ± 0.57 mg/100 g) and tannins (12.01 ± 0.31 mg/100 g) (Table 1 and 2).

The proximate analysis of the *C. albidum* leaves revealed carbohydrate content (46.71%), crude fibre (39.59%), moisture ($4.83 \pm 0.22\%$), ash ($3.35 \pm 0.14\%$), crude proteins ($3.21 \pm 0.08\%$) and crude fats ($2.33 \pm 0.01\%$) as seen in Table 3.

Table 1: Qualitative determination of the phytochemical screening of the leaves of *C. albidum* with ethanol as solvent

Phytochemical	Qualitative
Reducing sugar	+++
Anthocyanin	+
Flavonoids	+++
Tannins	+++
Alkaloids	+++
Total phenols	+++
Terpenoids	+++
Cardiac glycosides	+
Saponins	-
Steroid	-
Carbohydrate	++
Protein	+++
Resin	-

Heavily Present; +++; Slightly Present; ++; Present; +; Absent; -

Table 2: Table of quantitative phytochemicals of *C. albidum* leaves (mg/100 g)

Bioactive compound	Phytochemical quantity (mg/100 g)
Reducing sugar	15.69 ± 0.57
Anthocyanin	24.55 ± 0.29
Flavonoids	19.99 ± 0.37
Tannins	12.01 ± 0.31
Alkaloids	20.44 ± 1.77
Total phenols	27.79 ± 0.31
Terpenoids	21.15 ± 0.57
Cardiac glycosides	15.73 ± 0.09

All values expressed as mean ± SD of triplicates. Results are expressed on dry weight basis

Table 3. Proximate compositions of leaf extract of *C. albidum*

Proximate constituents	Compositions (%)
Moisture	4.83 ± 0.22
Crude fibre	39.59 ± 1.51
Ash	3.35 ± 0.14
Crude fats	2.33 ± 0.01
Crude proteins	3.21 ± 0.08
Carbohydrates	46.71 ± 1.51

Values expressed as mean ±SD of the three replicates

Histomorphology of the Beta- cells

The β cells were damaged as a result of the induction of diabetes. Group 2 (Figure 2) showed a decrease in the number of β cells of the islets of Langerhans when compared to the control group (Figure 1). Figure 3 showed few beta cells that are scattered when compared with the control group (Figure 1). There

was an increase in the number of β cells distributed throughout the islet in group 5 (Figure 5) and group 6 (Figure 6) after treatment with 250 and 500 mg/kg *C. albidum* leaf extract, respectively.

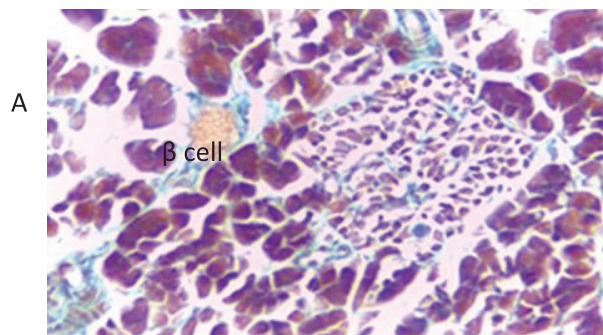


Figure 1. Photomicrograph of a pancreatic section from the control group showing the exocrine region and islets of Langerhans, with intact beta cells. A: Acinar cells, β cell: beta cells; modified aldehyde fuchsin staining, 400 \times .

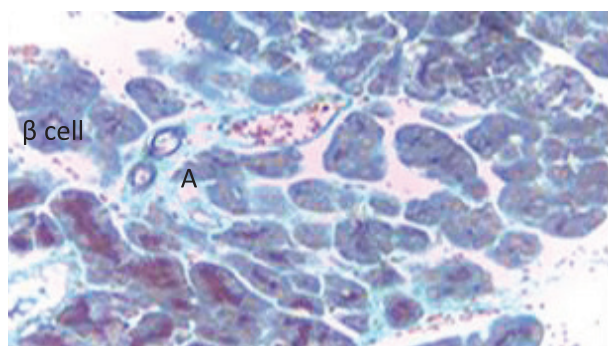


Figure 2. Photomicrograph of STZ-induced diabetic pancreatic section showing the exocrine region and islet shrinkage, degeneration of beta cells and vacuoles at periphery. A: Acinar cells, β cell: beta cells; modified aldehyde fuchsin staining, 400 \times .

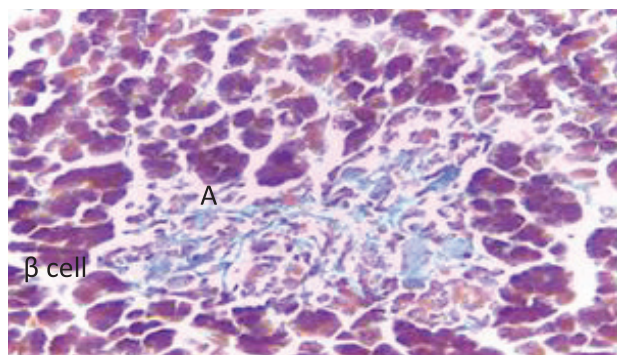


Figure 3. Photomicrograph of diabetic islet treated with glibenclamide showing beta cells. A: Acinar cells, β cell: beta cells; modified aldehyde fuchsin staining, 400 \times .

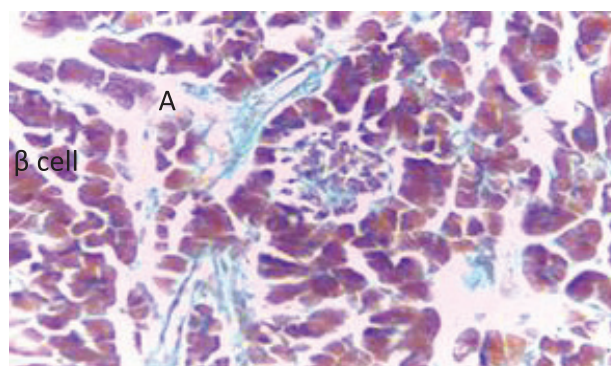


Figure 4. Photomicrograph of diabetic islet treated with 125 mg/kg of *C. albidum* leaf extract showing partial shrinkage and few beta cells. A: Acinar cells, β cell: beta cells; modified aldehyde fuchsin staining, 400 \times .

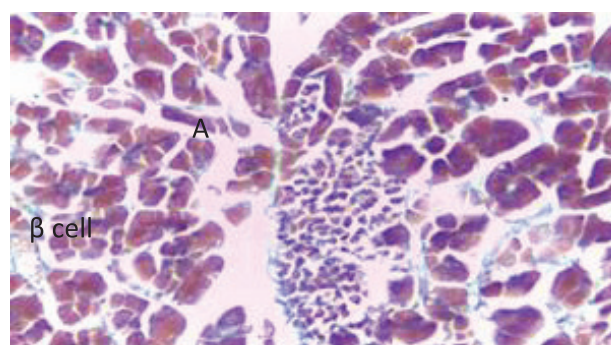


Figure 5. Photomicrograph of diabetic islet treated with 250 mg/kg of *C. albidum* leaf extract showing evenly distributed beta cells and an increased number of beta cells. A: Acinar cells, β cell: beta cells; modified aldehyde fuchsin staining, 400 \times .

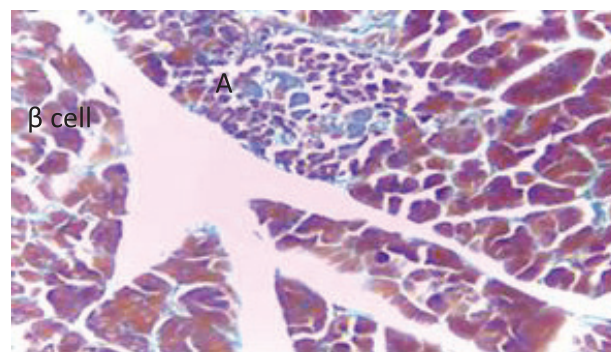


Figure 6. Photomicrograph of diabetic islet treated with 500 mg/kg of *C. albidum* leaf extract showing evenly distributed beta cells and an increased number of beta cells. A: Acinar cells, β cell: beta cells; modified aldehyde fuchsin staining, 400 \times .

Discussion:

Studies have identified and focused on the high concentration activity of natural compounds found in plants and their use to treat ailments³⁵.

The phytochemical analyses of the leaf extract of *C. albidum* revealed the presence of potent phytochemicals. The antioxidant potential of phenols have been demonstrated, and they act as free radical scavengers³⁶. Furthermore, phenols have a wide range of biological effects such as anti-arthrosclerosis, anti-inflammation, and endothelial function improved performance; cell proliferation activity, and cardiovascular protection³⁷. Flavonoids have antioxidant and anti-inflammatory properties³⁸. Flavonoids are also important in protecting biological systems from the harmful impacts of oxidation process on macromolecules³⁹.

Furthermore, flavonoids have been shown to regenerate pancreatic beta cells that have been destroyed in diabetes-induced rats using STZ, as well as to act on insulin release from beta cells^{40, 16}. Anthocyanins have been shown to have lot of health benefits, including antioxidant potential.⁴¹ Tannins have numerous biological properties, including antioxidant and anti-inflammatory⁴². As a result, tannin consumption has been linked to a lower onset of chronic ailments⁴³. Terpenoids are plant signaling compounds and phytohormones; anti-inflammatory and antihyperglycemic properties are among its medicinal properties.^{44, 45} Cardiac glycosides are known to be natural cardioactive agents that can be used to treat heart failure and arrhythmia^{46, 47}. Cardiac glycosides found in *C. albidum* may be responsible for the plant's folkloric use in cardiac diseases treatment. Furthermore, flavonoids, phenols, and terpenoids have been shown to have anti-diabetic activity and have been used to treat diabetes mellitus⁴⁸.

The proximate composition of *C. albidum* leaves revealed an elevated carbohydrate level, suggesting that they could be utilized as a source of energy. The low moisture content demonstrated that they are not susceptible to spoilage by microorganisms. The leaves had a low fat content, implying that they could be included in weight-loss diets. The crude fibre content of *C. albidum* leaves suggests that it may facilitate digestive process and soften stools, preventing constipation

Dietary fiber's ability to reduce serum levels of cholesterol can help reduce the likelihood of diseases such as diabetes and coronary heart disease⁴⁹. Besides this, the study indicated that the *C. albidum* contained a significant amount of essential

nutrients. These findings may be one of the reasons that support the practice of using *C. albidum* leaves in ethnomedicine.

STZ has a negative effect on pancreatic beta cells by generating reactive oxygen species, which make a significant contribution to DNA fragmentation⁵⁰ and, as a result, halt insulin production and release⁵¹. Because beta cells are vulnerable to oxidative stress due to their low intracellular capacity, oxidative molecules are important mediators of beta cell destruction⁵².

Histologically, diabetic pancreatic islets have the following characteristics such as; decreased islet number, beta cell degranulation, islet vacuolation, and inflammation^{53, 54}. According to these findings, the leaf of *C. albidum* contains antioxidants that can mitigate the cytotoxic action of STZ and stimulate a regenerative effect on beta cells. Furthermore, pre-treatment of diabetic pancreatic beta cells with *C. albidum* reduced blood glucose levels while increasing insulin secretion¹¹. However, the phytochemical's synergistic action may also have aided in beta cell regeneration. Furthermore, pre-treatment with *C. albidum* leaf extract protects the islets of Langerhans from STZ-induced pancreatic degeneration¹⁶. Therefore, *C. albidum* substantially attenuate STZ toxicity.

Conclusion:

Based on the research presented above, it is possible to deduce that this plant has enormous potential as a new oral agent(s) for the treatment of diabetes.

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Conflict of interest:

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

Authors' contribution:

Data gathering and idea owner of this study: Idaguko C. Anna

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