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Original Article

# Anti-hyperglycaemic activity of tuber extract of *Chlorophytum alismifolium* Baker in streptozotocin-induced hyperglycaemic rats

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ABSTRACT

The tubers of *Chlorophytum alismifolium* (Liliaceae) are widely used in Nigerian Herbal Medicine to treat diabetes mellitus and their efficacy is widely acclaimed among the rural communities of Northern Nigeria. This study was aimed at investigating the antihyperglycaemic potential of the tuber extract of *Chlorophytum alismifolium* (CAE) in streptozotocin-induced hyperglycaemic rats. Phytochemical screening and oral median lethal dose ($LD_{50}$) estimation of CAE in rats were carried out. Antihyperglycaemic screening of the extract (at oral doses of 150, 300 and 600 mg/kg) was performed using normal and streptozotocin-induced hyperglycaemic rats for 28 days. Fasting blood glucose levels were measured and serum lipids were analyzed. Liver, kidney, heart and pancreatic tissues were examined for histopathological damages using standard histological processing. Phytochemical screening revealed the presence alkaloids, saponins, flavonoids, triterpenes and glycosides. Oral $LD_{50}$ was estimated to be > 5000 mg/kg body weight in rats. *C. alismifolium* extract at all the doses tested showed blood glucose lowering effect. Statistical significant ($p < .01$) blood glucose lowering effect at 150 mg/kg on day 21, at 300 mg/kg on days 21 and 28 ($p < .001$ and $p < .01$ respectively) and 600 mg/kg on days 7, 14, 21 and 28 ($p < .05$, $p < .01$, $p < .001$ and $p < .01$ respectively) was produced by the extract. The extract also reduced the levels of total cholesterol, triglycerides and low density lipoprotein. Histopathological examination of the pancreas showed restoration of pancreatic islet cells at the doses of 300 and 600 mg/kg of the extract. In conclusion, the results obtained suggest the tuber extract of *Chlorophytum alismifolium* possesses antihyperglycaemic activity.

## 1. Introduction

Diabetes mellitus (DM) is a group of metabolic diseases in which a person has high blood sugar, either because the body does not produce enough insulin, or cells do not respond to the insulin that is produced [1]. The global prevalence of diabetes among adults has risen from 4.7% in 1980 to 8.5% in 2014 [2]. In 2012, diabetes was the direct cause of 1.5 million deaths and hyperglycaemia was the cause of another 2.2 million deaths [2]. DM is also associated with complications such as retinopathy, nephropathy, peripheral neuropathy, ketoacidosis, non-ketotic coma, cardiovascular diseases and genito-urinary complications [3]. Among several metabolic derangements, insulin deficiency stimulates lipolysis in the adipose tissues and results in hyperlipidemia [4].

Insulin and oral anti hyperglycaemic agents are not only expensive but also known to produce serious side effects such as hypoglycaemia, anorexia nervosa, brain atrophy and fatty liver [5] following chronic treatment. Biguanides and sulphonylureas are valuable in the management of type 2 DM but their use is also limited by side effects such as lactic acidosis, gastrointestinal tract disturbances and hypoglycaemia [6]. Therefore the search for cheaper, safer and effective agents for the management of DM has continued to be an important area of investigation [7].

The study of medicinal plants has led to the discovery of new chemicals for potential development as drugs that act on new or known therapeutic targets [8]. There has been a focus on the search for new drugs from medicinal plants that will be useful in management of DM [9]. The genus Chlorophytum contains 198 species which are valuable medicinal plants widely distributed in the tropical regions of the world especially in Africa and India [10]. The tubers of these species are the medicinally useful parts [11]. *Chlorophytum borivilianum* for example has been reported to possess anti hyperglycaemic, hypolipidemic and

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antimicrobial properties [12,13]. Similarly, *Chlorophytum nimmoni* possesses antidiabetic and hypolipidemic properties [14].

*Chlorophytum alismifolium* (Baker), a member of Liliaceae family is a short stem herb with tuberous root stocks and white flowers found around stony sites in forest streams [15]. It is commonly known as Alimsa-Ground lilly and locally known as *Rogon makwarwa* (Hausa) and *Cigorodi* (Fufulde). The tubers of *Chlorophytum alismifolium* are used in herbal medicine in Northern Nigeria for the treatment of DM, bacterial infections, arthritis, erectile dysfunction, pain and inflammation [16]. The efficacy of *Chlorophytum alismifolium* tubers in management of DM is widely acclaimed among the rural communities of Northern Nigeria; however, there is no scientific report to justify the folkloric claim for such use, hence this research was carried out to validate the aforementioned claim using experimental animal model.

## 2. Materials and methods

### 2.1. Drugs and chemicals

Streptozotocin (MP Biomedicals M 3219k, France), Glimepiride (Sanofi Aventis, D-65926 Frankfurt, Germany), 10% Dextrose and Normal saline (Dana pharmaceuticals, Nigeria), Glucometer and test strips (Accu-check Active, Roche, Germany), standard kits and photoelectric colorimeter (AC-115 Optima, Japan) for assay of low density lipoprotein (LDL), high density lipoprotein (HDL), triglyceride (TG) and total cholesterol (TC).

### 2.2. Experimental animals

Wistar albino rats (males) weighing 150–200 g were obtained from the laboratory Animal Facility, Department of Pharmacology and Therapeutics, Ahmadu Bello University, Zaria. The animals were maintained in a well-ventilated room, fed on standard animal feed and granted access to water *ad libitum*. The experimental protocols were approved by the University Animal Ethics Committee (Protocol number: DAC/IW-OT/212–15). The studies performed on the permitted species were in accordance with Ahmadu Bello University Research policy as well as ethic and regulations governing the care and use of experimental animals as contained in "Principles of laboratory animal care" published by the National Institute of Health (NIH Publication No. 85-23, revised, 1996).

### 2.3. Plant material

The tubers of *Chlorophytum alismifolium* were collected in July 2014 from *Tilden Fulani* River in Toro LGA, Bauchi State, Nigeria. The botanical identification and authentication was done by Mallam Musa Muhammed of the Herbarium Unit of the Department of Botany, Ahmadu Bello University, Zaria, Nigeria. A voucher number of 6785 was obtained and a voucher specimen was kept in the Herbarium for future reference.

### 2.4. Preparation of the CAE

The tubers were washed and chopped into smaller sizes and then air-dried under shade for three weeks until constant weight was attained. The dried plant was then crushed into fine powder using pestle and mortar. The powdered plant (1 kg) was extracted with 2.5 L of 90% $^{v}/_{v}$ aqueous methanol (90% methanol: 10% water) for 72 h using the soxhlet apparatus. The extract was concentrated to dryness on a water bath set at 50 °C and was stored in a desiccator until required for the main experiment. The extract was reconstituted freshly with distilled water for each study.

### 2.5. Phytochemical screening

Standard phytochemical screening tests [17,18] were employed in screening the plant extract. The extract was screened for the presence or absence of phytochemicals including alkaloids, flavonoids, saponins, glycosides, cardiac glycosides, tannins, anthraquinones, triterpenes and carbohydrates.

### 2.6. Extract and drug treatment

Stock solutions of the extract were prepared by dissolving it in deionized water followed by serial dilution to obtain the appropriate concentrations for the studies. Similarly, a stock solution of the standard drug, glimepiride was prepared by dissolving the powder in deionized water to obtain the appropriate concentration. The extracts and standard drug were administered orally using oral gavages. The drug solutions were usually prepared fresh for each day's experiment to maintain their stability.

### 2.7. Acute toxicity study

The method described by Lorke [19] was employed in the determination of the oral median lethal dose ($LD_{50}$) in rats. The test was in two phases; in phase one, three groups of animals (n = 3) were administered widely differing doses of the extract (10, 100 and 1000 mg/kg) and were observed for signs of toxicity and mortality for 24 h. In the second phase, 3 animals were administered 1600, 2900 and 5000 mg/kg of the extract and then observed for signs of toxicity and mortality for 24 h. The $LD_{50}$ was calculated as the geometric mean of the lowest lethal dose and highest non-lethal dose as presented below:

$$LD_{50} = \sqrt{\text{lowest lethal dose} \times \text{highest non-lethal dose}}$$

The doses of the extract used in the main study (150, 300 and 600 mg/kg) were less than 20% of the estimated $LD_{50}$.

### 2.8. Experimental induction of ***hyperglycaemia***

Experimental hyperglycaemia was induced using the method of Virendra et al. [20]. Streptozotocin (STZ) (50 mg/kg) was dissolved in ice cold citrate buffer (pH 4.5) immediately before use. The solution was injected intraperitoneally at the dose of 50 mg/kg in rats fasted for 12 h. The rats were given 10% glucose solution for 24 h to prevent mortality due to initial hypoglycemia induced by STZ. The animals were given food and water then observed over a period of 72 h for signs of hyperglycemia. The determination of glucose concentration was done using test strips which follows the Glucose Oxidase principles [21]. The animals with blood glucose levels above 200 mg/dL were considered hyperglycaemic and selected for further study.

### 2.9. Experimental design

The selected STZ-induced hyperglycaemic and normal rats were then assigned accordingly into six groups with each group containing six rats (n = 6). The normal saline, graded doses of CAE and glimepiride were administered orally and daily for 28 days

| | |
|---|---|
| Group I | Normal control group (Administered Normal saline 1 mL/kg) |
| Group II | Hyperglycaemic control group (Administered Normal saline 1 mL/kg) |
| Group III | Hyperglycaemic rats (Administered 150 mg/kg CAE) |
| Group IV | Hyperglycaemic rats (Administered 300 mg/kg CAE) |
| Group V | Hyperglycaemic rats (Administered 600 mg/kg CAE) |
| Group VI | Hyperglycaemic rats (Administered Glimepiride 10 mg/kg) |

### 2.10. Procedure of anaesthesia and biochemical estimations

The animals from all groups were anaesthetized with mild chloroform anaesthesia and blood samples were collected from the jugular veins on the 28th day in plain bottles and the serum thus obtained was used for biochemical analyses. The plasma Total Cholesterol (TC), triglycerides (TGs), low-density lipoprotein (LDL) and high density lipoprotein (HDL) were analyzed using a photoelectric colorimeter (AC-115 Optima, Japan).

### 2.11. Calculation of organ to body weight ratio

The liver, kidney, pancreas and heart of the rats in the various groups were excised on the 28th day after blood collection. Thereafter, the organs were trimmed of extraneous tissues, placed on a saline soaked gauze and then weighed (with paired organs weighed together) using a weighing balance (AE240 dual range, Metler Instrument Corporation, USA). The relative organ to body weight ratio was calculated using the formula:

$$\text{Organ body weight ratio (\%)} = \frac{\text{Organ weight (g)}}{\text{Final body weight (g)}} \times 100$$

### 2.12. Histopathology

The organs (pancreas, heart, liver and kidney) were fixed in 10% formaldehyde for 10 days, they were then processed to dehydrate, clear and infiltrate the tissues using paraffin wax. They were then embedded to allow orientation of the specimen in a block form that can be sectioned. Thin sections of the specimens were made using a microtome, placed on a microscope slide and then stained using haematoxylin and eosin. The sections were then examined microscopically for histopathological changes [22].

### 2.13. Statistical analyses

Statistical analysis was carried out using SPSS software (Version 20). Data obtained were analyzed using One Way Analysis of Variance (ANOVA) and repeated measure ANOVA where appropriate followed by Bonferroni post hoc test for multiple comparison; and values of $p < .05$ were considered statistically significant. Data were presented as Mean ± Standard Error of the Mean (S.E.M.) in tables and figure.

## 3. Results

### 3.1. Phytochemical screening

The methanol tuber extract of *Chlorophytum alismifolium* obtained was dark brown, sticky semi-solid substance with honey-like smell. The percentage yield of the extract of *Chlorophytum alismifolium* was 5.16%$^{w}/_{w}$. Preliminary phytochemical test revealed the presence of alkaloids saponins, flavonoids, glycosides, cardiac glycosides and triterpenes (Table 1).

**Table 1**
Phytochemical components of *Chlorophytum alismifolium* extract.

| Chemical compound | Test | Remark |
|---|---|---|
| Carbohydrates | Molisch test | + |
| Anthraquinones | Bontrager's test | − |
| Glycosides | Fehling's test | + |
| Cardiac glycosides | Keller-killiani test | + |
| Saponins | a. Frothing test | + |
| | b. Hemolysis test | + |
| Tannins | Ferric-chloride test | − |
| Flavonoids | a. Shinoda test | + |
| | b. Sodium hydroxide test | + |
| | c. Ferric chloride test | + |
| Alkaloids | a. Mayer's test | + |
| | b. Dragendorff's test | + |
| | c. Wagner's test | + |
| Triterpenes | Liebermann-Burchard test | + |
| Steroids | Salkowski test | − |

Key: Absent (−), Present (+).

**Table 2**
Determination of median lethal dose ($LD_{50}$) of methanol tuber extract of *Chlorophytum alismifolium* in rats.

| Phase one doses (mg/kg) | Number of rats used | Mortality |
|---|---|---|
| 10 | 3 | 0/3 |
| 100 | 3 | 0/3 |
| 1000 | 3 | 0/3 |
| **Phase two doses (mg/kg)** | **Number of rats used** | **Mortality** |
| 1600 | 1 | 0/1 |
| 2900 | 1 | 0/1 |
| 5000 | 1 | 0/1 |

### 3.2. $LD_{50}$ determination

The $LD_{50}$ of the crude methanol extract of *C. alismifolium* was estimated to be > 5000 mg/kg body weight in rats and no adverse symptoms or death was recorded in both phases of the experiment (Table 2).

### 3.3. Effect of methanol crude extract of C. alismifolium on blood glucose level of STZ-induced hyperglycemic rats

*C. alismifolium* produced a significant ($p < .05$) and ($p < .01$) blood glucose lowering effect at a dose of 600 mg/kg on days 7 and 14 respectively when compared to hyperglycaemic control. On day 21, there was a significant ($p < .01$) decrease in blood glucose level at 150 mg/kg and ($p < .001$) at 300 and 600 mg/kg respectively compared to the hyperglycaemic control. Similarly, on day 28, the extract at 300 and 600 mg/kg significantly ($p < .01$) lowered the blood glucose level when compared to hyperglycaemic control. The results were also compared over time by comparing day 0 with days 7, 14, 21 and 28. The extract at 600 mg/kg significantly ($p < .001$) reduced the blood glucose level on all the days when compared to day 0; while at 300 mg/kg, the reduction was significant ($p < .001$) only on days 14, 21 and 28 compared to day 0 (Fig. 1).

### 3.4. Effect of 28-day oral daily administration of methanol extract of Chlorophytum alismifolium on lipid profile of streptozotocin-induced hyperglycaemic rats

*C. alismifolium* extract provided a dose-dependent decrease in LDL

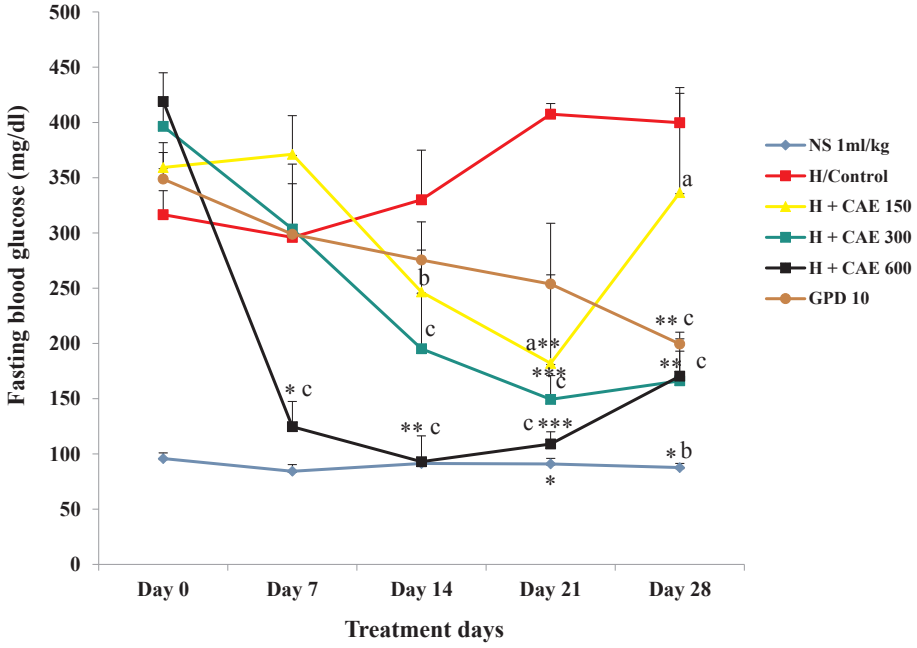


**Fig. 1.** Effect of daily administration of *Chlorophytum alismifolium* methanol extract on fasting blood glucose in streptozotocin-induced hyperglycemic rats. Values are presented as Mean ± S.E.M; * = p < .05, ** = p < .01, *** = p < .001 compared to diabetic control group; a, b and c represent p < .05, p < .01 and p < 0.001 compared to day 0 – repeated measure ANOVA followed by Bonferroni post hoc test. CAE-*Chlorophytum alismifolium* extract, H = Hyperglycaemic, N/S = Normal saline, GPD = Glimepiride, n = 6.

**Table 3**
The effect of 28-day oral daily administration of methanol extract of *Chlorophytum alismifolium* on lipid profile of streptozotocin-induced hyperglycemic rats.

| Treatment (mg/kg) | TC (mmol/L) | HDL (mmol/L) | LDL (mmol/L) | TG (mmol/L) |
|---|---|---|---|---|
| N/S 1 ml/kg | 2.33 ± 0.25 | 0.40 ± 0.08 | 1.03 ± 0.14 | 1.22 ± 0.13 |
| H/Control | 2.48 ± 0.21 | 0.50 ± 0.08 | 1.45 ± 0.24 | 1.93 ± 0.15 |
| H + CAE 150 | 2.03 ± 0.13 | 0.40 ± 0.08 | 1.15 ± 0.06 | 1.00 ± 0.14 |
| H + CAE 300 | 2.13 ± 0.50 | 0.50 ± 0.13 | 1.10 ± 0.31 | 1.03 ± 0.10 |
| H + CAE 600 | 1.92 ± 0.21 | 0.45 ± 0.10 | 0.90 ± 0.08 | 0.98 ± 0.28 |
| GPD 10 | 1.55 ± 0.31 | 0.30 ± 0.08 | 0.63 ± 0.21 | 1.30 ± 0.30 |

Values are presented as Mean ± S.E.M, No statistical significant difference compared to hyperglycaemic control – one way ANOVA followed by Bonferroni test, n = 6, TC = Total Cholesterol, HDL = High Density lipoprotein, LDL = Low Density lipoprotein, TG = Triglycerides, CAE = *Chlorophytum alismifolium* Extract, N/S = Normal saline, GPD = Glimepiride.

**Table 4**
Effect of 28-day oral daily administration of methanol extract of *Chlorophytum alismifolium* on body weight of streptozotocin-induced hyperglycemic rats.

| Treatment (mg/kg) | Initial body weight (g) | Final body weight (g) |
|---|---|---|
| Normal saline 1 ml/kg | 197.83 ± 19.82 | 207.33 ± 19.11 |
| H/Control | 197.00 ± 18.65 | 155.00 ± 25.45*** |
| H + CAE 150 | 193.33 ± 14.56 | 167.00 ± 2.28* |
| H + CAE 300 | 192.00 ± 13.42 | 165.50 ± 11.72** |
| H + CAE 600 | 191.17 ± 12.54 | 215.80 ± 15.27** |
| Glimepiride 10 | 193.75 ± 12.90 | 166.00 ± 20.69** |

Values are presented as Mean ± S.E.M; * = $p < .05$, ** = $p < .01$, *** = $p < .001$ compared to initial body weight – repeated measure ANOVA followed by Bonferroni post hoc test, n = 6, CAE = *Chlorophytum alismifolium* extract, H = Hyperglycaemic, GDP = Glimepiride, n = 6.

compared to hyperglycaemic control group. A non-dose dependent decrease in TGs was also observed at 600 mg/kg, though not statistically significant ($p > .05$) when compared to hyperglycaemic control group. The extract also increased the level of HDL at 300 mg/kg (Table 3).

### 3.5. Effect of 28-day oral daily administration of the methanol extract of Chlorophytum alismifolium on body weight of steptozotocin-induced hyperglycaemic rats

A significant ($p < .001$) reduction in body weight of the hyperglycaemic control rats was observed when compared to the initial body weight. There was also a significant ($p < .05$ and $p < .01$) reduction in body weight at 150 and 300 mg/kg respectively when compared to initial body weight. However, a significant ($p < .05$) increase in body weight was observed at 600 mg/kg (Table 4).

### 3.6. Effect of methanol extract of Chlorophytum alismifolium on relative organ to body weight ratio of streptozotocin-induced hyperglycaemic rats following 28-days oral daily administration

There was no significant difference ($p > .05$) in the relative organ to body weight ratios of the liver, kidney, pancreas and heart at all the doses of the extract tested (150, 300 and 600 mg/kg) when compared to hyperglycaemic control (Table 5).

**Table 5**
Effect of methanol extract of *Chlorophytum alismifolium* on relative organ to body weight ratio of streptozotocin-induced hyperglycaemic rats following 28-days oral daily administration.

| Treatment (mg/kg) | Organ to body weight ratio (%) | | | |
|---|---|---|---|---|
| | Liver | Kidney | Pancreas | Heart |
| N/S 1 ml/kg | 4.32 ± 0.25 | 0.79 ± 0.10 | 0.54 ± 0.04 | 0.48 ± 0.03 |
| H/Control | 4.91 ± 0.69 | 1.05 ± 0.17 | 0.37 ± 0.09 | 0.60 ± 0.09 |
| H + CAE (1 5 0) | 4.63 ± 0.36 | 0.96 ± 0.04 | 0.31 ± 0.03 | 0.50 ± 0.02 |
| H + CAE (3 0 0) | 2.89 ± 0.17 | 0.83 ± 0.10 | 0.37 ± 0.03 | 0.40 ± 0.04 |
| H + CAE (6 0 0) | 3.00 ± 0.13 | 0.58 ± 0.07 | 0.42 ± 0.04 | 0.38 ± 0.02 |
| GPD (10) | 4.52 ± 0.65 | 0.96 ± 0.12 | 0.34 ± 0.05 | 0.45 ± 0.05 |

Data are presented as Mean ± S.E.M; No significant difference compared to diabetic control – one way ANOVA followed by Bonferroni post hoc test; n = 3, CAE = *Chlorophytum alismifolium* extract, N/S = Normal saline, GPD = Glimepiride, H = Hyperglycaemic.

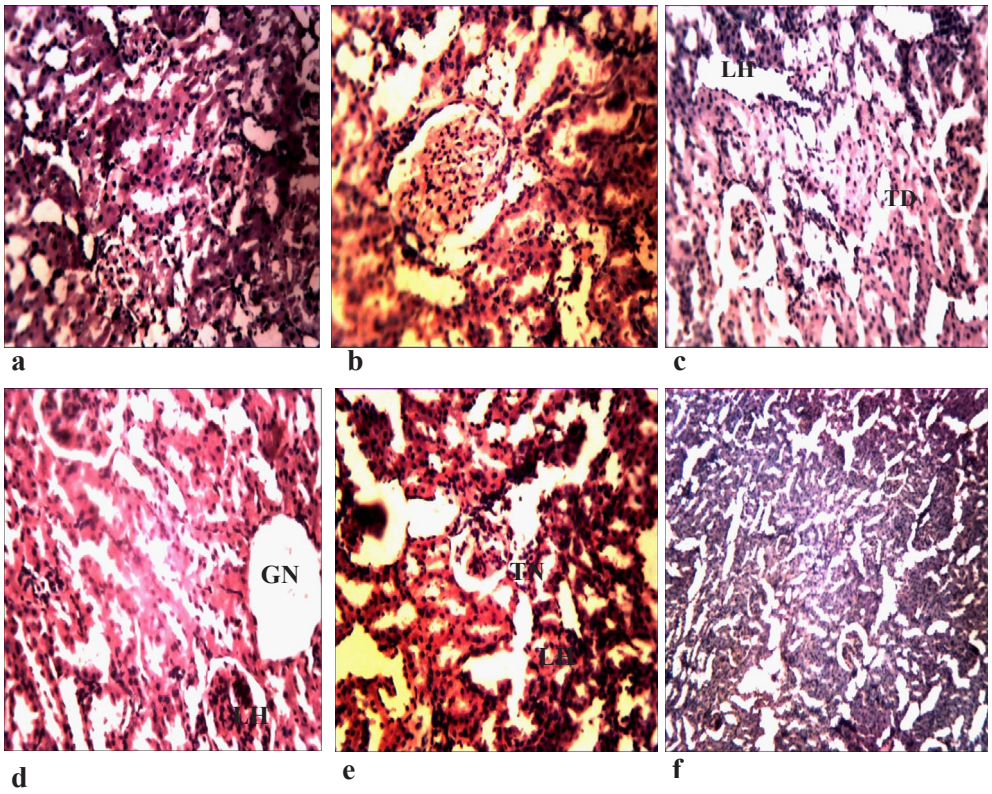


**Plate 1.** Photomicrograph of the kidney showing glomerular necrosis (GN), tubular necrosis (TN), tubular destruction (TD) and lymphocyte hyperplasia (LH) in streptozotocin-induced hyperglycaemic rats (H and E x 250). a = normal rats, b = streptozotocin-induced hyperglycaemic rats, c = hyperglycaemic rats treated with CAE (150 mg/kg), d = hyperglycaemic rats treated with CAE (300 mg/kg), e = hyperglycaemic rats treated with CAE (600 mg/kg), f = hyperglycaemic rats treated with Glimepiride (10 mg/kg), CAE = *Chlorophytum alismifolium* extract.

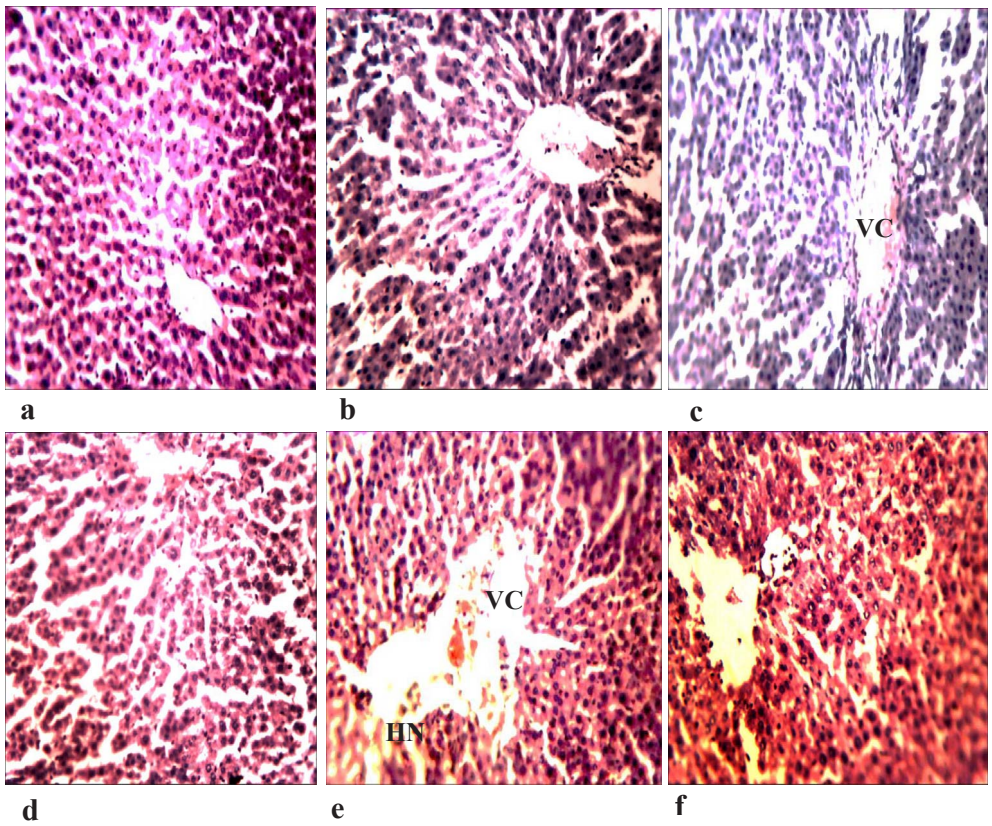


**Plate 2.** Photomicrograph of the liver showing Hepatocellular necrosis (HN), Vacoulations (V) and Vascular congestion (VC), in streptozotocin-induced hyperglycaemic rats (H and E x 250). a = normal rats, b = streptozotocin-induced hyperglycaemic rats, c = hyperglycaemic rats treated with CAE (150 mg/kg), d = hyperglycaemic rats treated with CAE (300 mg/kg), e = hyperglycaemic rats treated with CAE (600 mg/kg), f = hyperglycaemic rats treated with Glimepiride (10 mg/kg), CAE = *Chlorophytum alismifolium* extract.

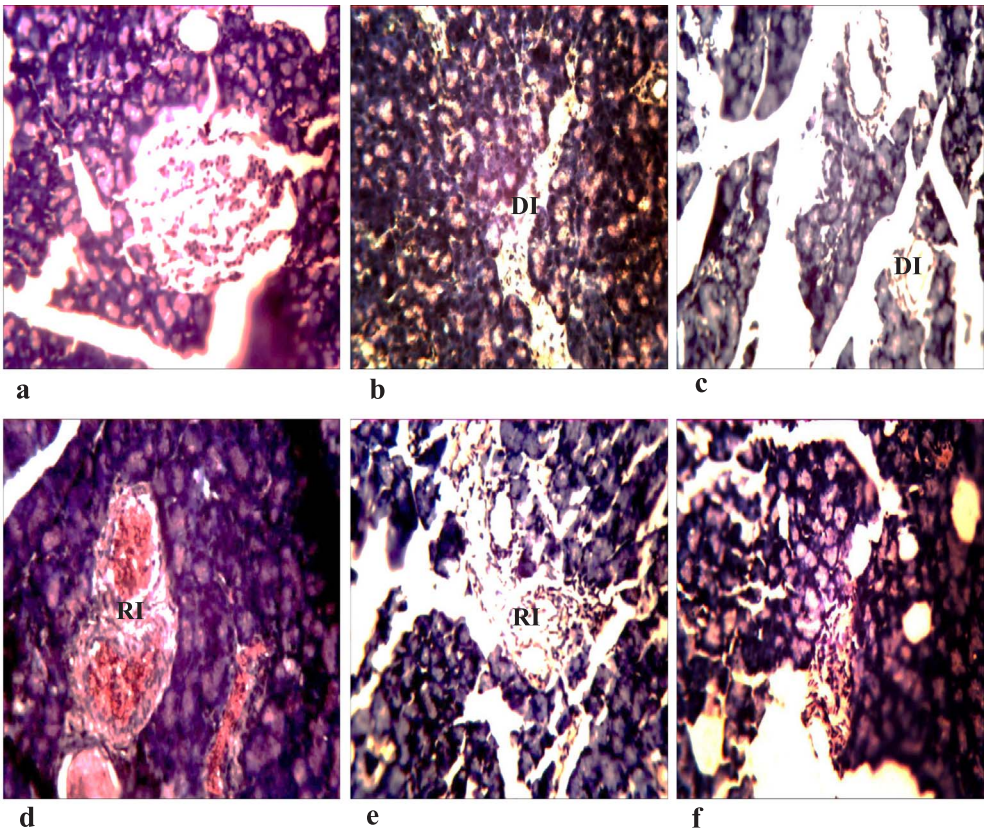


**Plate 3.** Photomicrograph of the pancreas showing Destroyed Islets (DI) and regenerated islets (RI) in streptozotocin-induced hyperglycaemic rats (H and E x 250). a = normal rats, b = hyperglycaemic control, c = hyperglycaemic rats treated with CAE (150 mg/kg), d = hyperglycaemic rats treated with CAE (300 mg/kg), e = hyperglycaemic rats treated with CAE (600 mg/kg), f = hyperglycaemic rats treated with Glimepiride (10 mg/kg) CAE = *Chlorophytum alismifolium* extract.

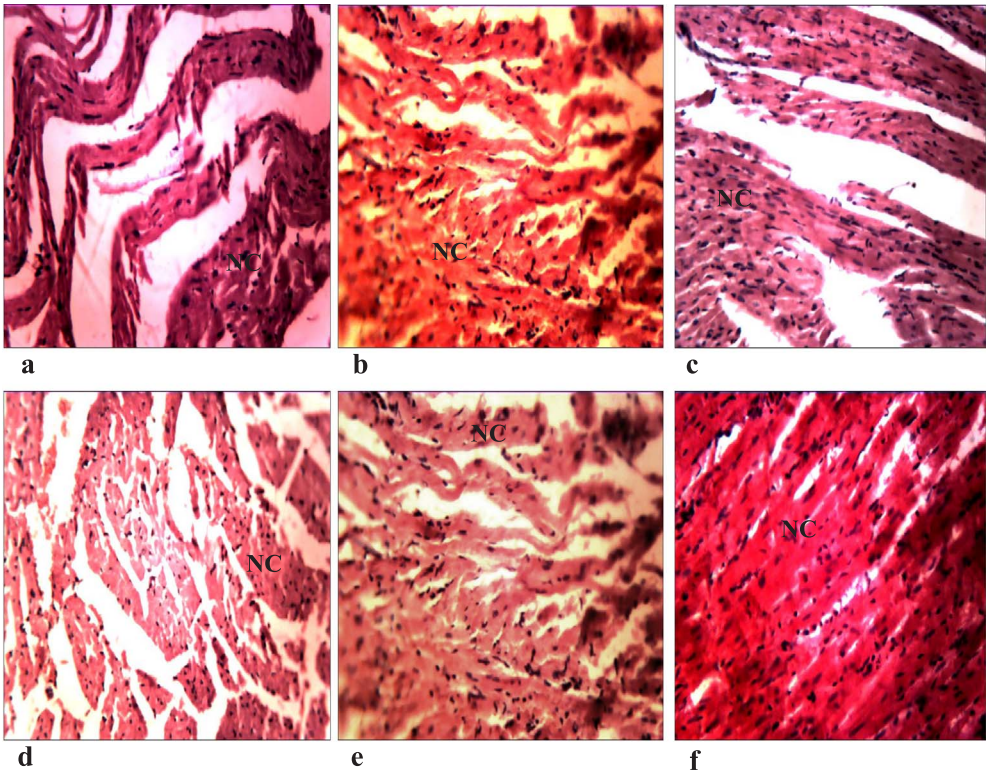


**Plate 4.** Photomicrograph of the heart showing intact cardiac cells (NC) in streptozotocin-induced hyperglycaemic rats (H and E x 250). a = normal rats, b = hyperglycaemic control, c = hyperglycaemic rats treated with CAE (150 mg/kg), d = hyperglycaemic rats treated with CAE (300 mg/kg), e = hyperglycaemic rats treated with CAE (600 mg/kg), f = diabetic rats treated with Glimepiride (10 mg/kg), CAE = *Chlorophytum alismifolium* extract.

### 3.7. Effects of 28-day oral daily administration of C. alismifolium on histopathology of the kidney, liver, pancreas and heart of streptozotocin-induced hyperglycaemic rats

Histopathology of the kidney showed glomerular tubular necrosis, tubular destruction, lymphocyte hyperplasia and tubular damage (Plate 1b, c, d, e and f). Histopathology of the liver showed vascular congestion, hepatocellular necrosis and vacoulations (Plate 2b, c, d, e and f). In the pancreas, islets destruction was observed in the diabetic group and the extract at 150 mg/kg. However, at 300 and 600 mg/kg of the extract, regeneration of the islets was observed (Plate 3b, c, d and e). Histopathology of the heart showed intact cardiac cells in all the groups (Plate 4a, b, c, d, e and f).

## 4. Discussion

Determination of the median lethal dose value of plants used in traditional medicine using acute toxicity study is of paramount importance because it provides information regarding their margin of safety [23]. The acute toxicity study indicated that the extract at a dose of 5000 mg/kg caused neither visible signs of toxicity nor mortality at both phases of the experiment, suggesting its apparent safety in rats if used orally.

The choice of STZ to induce diabetes in rats is widely utilized due to its specificity in destroying only the pancreatic β cells of islets of Langerhans. Several studies have reported that STZ-induced DM and insulin deficiency lead to increased blood glucose levels [24]. The damage done by STZ to the pancreatic β cells is not complete. The lowering of blood glucose levels after repeated doses of glimepiride in the positive control group was expected because glimepiride is a sulphonylurea and an established insulin secretagogue which stimulates insulin secretion by inhibition of ATP-dependent potassium channel and sets the β cells resting membrane potential. A reduction of potassium outflow causes β cell depolarization and the activation of calcium channels. The resulting calcium influx triggers exocytosis and release of insulin [25]. Administration of STZ also causes an increase in blood glucose levels which may be due to deficiency in insulin or resistance state in diabetic rats [26]. In this study, the daily administration of the methanol extract of *C. alismifolium* (150, 300 and 600 mg/kg) orally for 28 days significantly reduced the fasting blood glucose levels when compared to hyperglycaemic control rats. The possible mechanism of action through which the plant extract elicits its antihyperglycaemic effect could be through the stimulation of insulin secretion from the existing β cells within the pancreas [27] and or enhancing the regeneration of pancreatic β cells following their destruction by STZ [28] which will consequently increase the secretion of insulin. These hypotheses are corroborated by the histology of the pancreas which showed regeneration of the islet cells following administration of the extract (Plate 3d, e) [29].

Hypercholesterolemia and hypertriglyceridemia are common lipid abnormality in persons with type 2 DM [30]. Hypertriglyceridemia typically occurs in conjunction with low HDL levels and atherogenic small dense LDL particles and is associated with increased cardiovascular risk [31]. In this study, high levels of total cholesterol, TG and LDL was observed with the hyperglycaemic animals which could be due to increased mobilization of free-fatty acids from peripheral adipose tissues [32]. Administration of graded doses of *C. alismifolium* extract decreased the levels of total cholesterol, TG and LDL in the hyperglycemic rats. Though not statistically significant, it could be advantageous in preventing some complications related to DM like atherosclerosis and coronary heart disease.

STZ produces a diabetic state which is characterized by weight loss as a result of fat and protein catabolism [26,33]. Similarly, the induction of hyperglycaemia in this study resulted in decreased body weight of the animals. However, administration of *C. alismifolium* extract at 600 mg/kg significantly improved the body weight. This could be attributed to enhanced insulin activity which improved glucose utilization and reduced catabolism of fats and proteins.

STZ as a diabetogenic agent is hepatotoxic and nephrotoxic [34]. The histology of the kidneys and liver in this study showed abnormal features which could be attributed to toxicity of STZ. The pancreas however showed slight regeneration of islet cells at 300 mg/kg and a better regeneration was observed at 600 mg/kg of the extract. This further justifies the antihyperglycaemic activity of the methanol extract of *C. alismifolium*.

The efficacy of medicinal plants as antidiabetic agents may be attributed to one or more phyto-active components responsible for blood glucose reduction [35]. There are reports linking some phytochemical compounds as antihyperglycaemic agents. Phytochemicals like steroids [36], terpenoids [37] and saponins [38,39] have been shown to have blood glucose lowering activity. Flavonoids have been reported to regenerate damaged beta cells in diabetic rats [40]. In this study, phytochemical analysis of the tuber extract of *C. alismifolium* clearly elaborated the presence of some of the aforementioned active principles (Table 1). These phyto-constituents could be responsible for the regeneration of the damaged β cells following the administration of STZ (Plate 3) and the observed antihyperglycaemic activity.

## 5. Conclusion

The findings from this research revealed that *Chlorophytum alismifolium* tubers contain bioactive principles with antihyperglycaemic activity. This provides scientific basis for the folkloric claim of its use in the management of diabetes mellitus. Further investigations are ongoing to elucidate its mechanism(s) of antihyperglycaemic activity.

## Conflict of interest

The authors declared no conflict of interest.

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## Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.bfopcu.2017.11.003.

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