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Original Article

Ethanolic Extract of *Chrysophyllum albidum* Stem Bark Prevents Alloxan-Induced Diabetes

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Abstract

Chrysophyllum albidum (C. *albidum*) is traditionally used for the treatment of diabetes, but there is a paucity of scientific evidence to support its use. This study investigated the effect of the ethanolic extract of *Chrysophyllum albidum* stem bark (EECA) on alloxan-induced diabetic rats. Normal and alloxan-induced diabetic rats were randomly divided into groups and treated with 100-200 mg/kg EECA for 7, 14 and 28 days respectively. Metformin (150 mg/kg) was used as the standard control. Blood samples were collected at the end of treatment for glucose test, while serum samples were extracted and assessed for high density lipoprotein (LDLC), triglyceride (TG) low density lipoprotein cholesterol (LDLC) and total cholesterol (TC). Pancreas was excised and evaluated for oxidative stress indexes. Blood glucose, serum TG, LDL-C and TC levels were significantly ($p<0.001$) increased whereas HDL-C levels were significantly ($p<0.001$) decreased in diabetic rats when compared to non-diabetic. Also, pancreatic malondialdehyde levels were significantly ($p<0.001$) increased whereas superoxide dismutase, glutathione, catalase, and glutathione peroxidase levels were significantly ($p<0.001$) decreased in diabetic rats when compared to non-diabetic control. However, alterations in the aforementioned parameters were reversed significantly in a dose and time-dependent fashion in diabetic rats treated with 100 mg/kg ($p<0.05$), 200 mg/kg ($p<0.01$) and 400 mg/kg ($p<0.001$) of EECA for 7, 14 and 28 days respectively when compared to diabetic control. EECA showed potential as remedy for diabetes which supports its use in folklore for the treatment of diabetes.

Keywords: alloxan; *Chrysophyllum albidum;* diabetes; treatment; rat

Introduction

Hyperglycemia and dyslipidemia, among other disorders, are metabolic syndromes associated with dysfunctional endocrine system clinically referred to as diabetes mellitus (DM) (Mohini *et al*., 2012). DM is a common endocrine disorder affecting more than 200 million people worldwide. The dilapidating action of DM qualifies it as a disease of major public health concern and epidemiological survey showed that it is the seventh leading cause of death in the world (Ene *et al*., 2007). Many distinct types of DM exist and the etiology being a complex interaction of genetics, environmental factors and life-style choices (Susan and Helseth, 1997). In addition to hyperglycemia the metabolic deregulation associated with DM causes secondary pathophysiologic changes in multiple organ systems that impose a tremendous burden on the individuals with diabetes and on the health care system (Kronenberg, 2013). Diabetes tends to damage cell membranes which have been associated with increased free radical production. This shows oxidative stress through the generation of free radical appears to play a critical role in the pathogenesis of DM (Harnett *et al*., 2000). Orthodox medicines have played vital function in the management of diabetes however, situations which include toxicities, medication cost and treatment failure, created alternative quests for herbal remedies for the management of DM (Annapurna *et al*., 2001).

Herbs are sources of potential therapeutic agents against various diseases due to their biodiversity and the presence of a wide array of bioactive phytochemicals and secondary metabolites (Farombi, 2003). *C. albidum* is a plant used in folklore medicine due to its therapeutic values. The bark is used for the treatment of yellow fever and malaria while the leaf is used as an emollient and for the treatment of skin eruptions, stomach ache and diarrhoea (Adisa, 2000). The leaf and seed cotyledon have been reported to possess anti-hyperglycemic and hypolipidemic effects (Olorunnisola *et al*., 2008). It has antimicrobial, anti-nociceptive, anti-

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inflammatory and anti-oxidant activities. It serves as a natural anti-oxidant booster to remove free radicals from oxidative stress associated disorders (Idowu *et al*., 2006). The fleshy pulp of the fruit is eaten especially as snacks and its fruit has been found to have the highest ascorbic acid content than oranges and guava (Amusa *et al*., 2003). Tannins, flavonoids, terpenoids, proteins, carbohydrates and resins are the phytochemicals that have been reported in *C. albidum* (Okoli and Okere, 2010). Furthermore, the stem bark has been used in folklore for the treatment of diabetes with no scientific evidence. Therefore, the present study was designed to evaluate the anti-diabetic potential of the ethanolic extract of *C. albidum* stem bark (EECA) in alloxan-induced diabetic rats.

Materials and Methods

Drug and chemicals

Metformin was used as a standard control and alloxan monohydrate was used for the induction of diabetes in rats.

Plant

Collection and identification of plant material

The stem barks of *C. albidum* were obtained on March, 14th 2016 from Obelle town in Ikwere Local Government Area of Rivers State, Nigeria. The stem barks were botanically identified by Mr Kola Adeleke of the department of Pharmacognosy, Madonna University, Nigeria.

Preparation of plant extract

The stem barks of the tree of *C. albidum* were air dried and powdered using a mechanical grinder. 500 g of the powder was macerated with ethanol (1900 ml) for 72 hours with constant shaking. The extract was then filtered after 72 hours and the filtrate concentrated using a rotary evaporator. The yield of the extract was found to be 29.52 g which was stored in a refrigerator for further use.

Phytochemical analysis

The tests for flavonoid, tannin, protein, carbohydrate, saponin, alkaloid, glycoside, reducing sugar and steroid were carried out based on the procedures outlined by Harborne (1998).

Animal

Adult albino rats (200-220 g) were used for this study. They were kept in the animal house of the Department of Pharmacology and Toxicology, Madonna University, Nigeria. They were allowed to acclimatize for 1 week prior to the experiment during which they were introduced to growers mash. The rats were housed in clean gauzed cages having free access to feed and water *ad libitum*.

Acute toxicity test

This was carried out in 2 phases using modified Lorke's method, 1998. In phase 1, nine rats divided into 3 groups containing 3 rats each were used. The 3 groups were administered with 10 mg/kg, 100 mg/kg and 1000 mg/kg of EECA respectively. The rats were observed for 24 hours for behavioral changes and mortality. Phase 2 used 3 rats divided into 3 groups of 1 rat each. The rats were administered with 1500, 2500 and 5000 mg/kg of EECA and observed for 24 hours for behavioral changes and mortality. The LD50 was not calculated because there was no mortality, although some changes such as sluggish behavior, reduced appetite and thirst were observed.

Preparation of diabetic rats

The rats were made diabetic by intravenously injecting 150 mg/kg of alloxan monohydrate dissolved in normal saline (Akhtar *et al*., 2011). After 72 hours, the induction of diabetes was confirmed by measuring blood glucose levels using glucometer. The rats with blood glucose levels of 250-500 mg/dL were considered diabetic and used for the study (Olajide *et al*., 2004).

Grouping of rats and drug administration

- Group A contained 45 rats divided into 3 groups of 15 rats each. Rats were treated orally with 100, 200 and 400 mg/kg of EECA for 7, 14 and 28 days respectively
- Group B contained 15 rats divided into 3 groups of 5 rats each which served as non-diabetic control. Rats were treated orally with 0.2 mL of normal saline for 7, 14 and 28 days respectively.
- Group C contained 15 rats divided into 3 groups of 5 rats which served as diabetic control.
- Group D contained 15 diabetic rats divided into 3 groups of 5 rats each which were treated orally with the standard drug (150 mg/kg of metformin) daily for 7, 14 and 28 days respectively
- Group D contained 15 diabetic rats divided into 3 groups of 5 rats each which were treated orally with 100 mg/kg, 200 mg/kg and 400 mg/kg of EECA for 7, 14 and 28 days respectively.

Animal sacrifice

On the 29th day, the rats were sacrificed under anesthesia using diethyl ether and blood samples were collected from the heart. Two milliliter of blood samples were collected into fluoride oxalate-bottles for blood glucose analysis. Also, 4 mL of blood samples were collected into plain sample bottles for lipid profile evaluation. Blood glucose was evaluated using glucometer whereas serum total cholesterol (TC), triglyceride (TG), low density lipoprotein cholesterol (LDL-C) and high density lipoprotein cholesterol (HDL-C) were evaluated using commercial laboratory test kits (Randox Diagnostics, Crumlin, UK). Low density lipoprotein cholesterol (LDL-C) was estimated as reported by Friedewald *et al*. (1972). Pancreas was exercised rinsed in cold 1.05 % KCL solution then homogenized with 0.1M phosphate buffer (pH 7.2). The homogenate was centrifuged at 1200 rpm for 15 min and the supernatant was decanted and evaluated for oxidative stress markers. Pancreas total protein was determined according to Gonall *et al*. (1949) whereas malondialdehyde (MDA) was assayed as reported by Buege and Aust (1978). Reduced glutathione (GSH) was evaluated as reported by Sedlak and Lindsay 1968 whereas superoxide dismutase (SOD) was measured as reported by Sun and Zigma (1978). Catalase (CAT) was

analysed using the method of Aebi (1984) whereas glutathione peroxidase (GPX) assayed according to Rotruck *et al*. (1973).

Statistical analysis

Data are expressed as mean ± SEM and were subjected to one way analysis of variance (ANOVA) test followed by Dunnett's *post hoc* test using Graph Pad Prism version 5.01. Results were considered to be significant at $p<0.05$; <0.01 and <0.001.

Results

The phytochemical evaluation of EECA showed high presence of flavonoids, alkaloids and tannins (Table 1). No mortality was observed during the evaluation of the LD50 of EECA however, at the highest dose (5000 mg/kg) there were behavioral changes such as sluggish movements, lack of appetite and thirst (Tables 2 and 3). Furthermore, 100 mg/kg, 200 mg/kg, and 400 mg/kg of EECA did not produce significant ($p>0.05$) effects on glucose levels in normal rats when compared to non-diabetic control (Table 4). On the other hand, glucose levels were significantly ($p<0.001$) increased in diabetic rats when compared to non-diabetic control. However, glucose levels were significantly decreased in a dose and time-dependent fashion in diabetic rats administered with 100 mg/kg ($p<0.05$), 200 mg/kg ($p<0.01$) and 400 mg/kg ($p<0.001$) of EECA when compared to diabetic control. Comparatively, decreases in glucose levels produced at 400 mg/kg of EECA were not different when compared to metformin (Table 4). Serum TG, TC, LDL and HDL-C levels were normal ($p>0.05$) in normal rats treated with 100 mg/kg, 200 mg/kg and 400 mg/kg of EECA when compared to non-diabetic control (Tables 5-8). Nevertheless, significant increases ($p<0.001$) in serum TG, TC and LDL-C levels with significant ($p<0.001$) decreases in serum HDL-C levels were obtained in diabetic rats when compared to non-diabetic control (Tables 5-8). Interestingly, in a dose and time-dependent fashion, the levels of TG, TC, LDL-C were significantly decreased whereas HDL-C levels were significantly increased in rats treated with 100 mg/kg ($p<0.05$), 200 mg/kg ($p<0.01$) and 400 mg/kg ($p<0.001$) of EECA for 7, 14 and 28 days respectively when compared to diabetic rats. The restored levels of TG, TC, LDL and HDL-C obtained in 400 mg/kg of EECA -treated rats did not differ from metformin-treated rats. Furthermore, normal ($p>0.05$) levels of pancreatic GSH, CAT, SOD, GPX and MDA were observed in normal rats treated with 100 mg/kg, 200 mg/kg, and 400 mg/kg of EECA for 7, 14 and 28 days respectively when compared to non-diabetic control (Table 6). In sharp contrast, pancreatic levels of GSH, CAT, SOD and GPX were significantly ($p<0.001$) decreased whereas MDA levels were significantly ($p<0.001$) increased in diabetic rats when compared to non-diabetic control. However, the levels of the aforementioned parameters were significantly restored in a dose and time-dependent fashion in diabetic rats treated with 100 mg/kg ($p<0.05$), 200 mg/kg ($p<0.01$) and 400 mg/kg ($p<0.001$) of EECA for 7, 14 and 28 days respectively when compared to diabetic control (Table 9).

Table 1. Phytochemicals evaluation of the ethanolic stem bark extract of *C. albidum*

Phytochemicals	Results
Flavonoid	++
Tannin	++
Protein	++
Carbohydrate	+
Saponin	++
Alkaloid	++
Steroid	-
Glycoside	+
Reducing sugar	-

Key : ++= High, += Moderate, - = Absent

Table 2. Phase 1 of acute toxicity test

Dose	No of death
10 mg/kg	0/3
100 mg/kg	0/3
1000 mg/kg	0/3

Table 3. Phase 2 of acute toxicity test

Dose	No of death
1500 mg/kg	0/1
2500 mg/kg	0/1
5000 mg/kg	0/1

Table 4. Effect of *Chrysophyllum albidum* on glucose level of alloxan-induced diabetic rats

Dose (mg/kg)	7 days (mg/dL)	14 days (mg/dL)	28 days (mg/dL)
Control	80.9±7.00	82.4±7.33	80.7±6.45
CA 100	79.1±6.31	77.8±5.42	76.7±6.12
CA 200	77.5±5.43	76.6±5.00	74.9±7.53
CA 400	74.7±5.20	74.5±6.51	72.7±6.21
Diabetic Control (DC)	400.8±15.2[a]	389.6±11.7[a]	380.1±12.7[a]
DC +Metformin	150.9±10.1[b]	121.6±9.57[b]	100.1±9.62[b]
DC +EECA 100	301.3±13.6[c]	250.1±13.6[c]	201.8±11.8[c]
DC +EECA 200	252.7±12.6[d]	200.6±11.9[d]	150.2±10.3[d]
DC +EECA 400	161.8±11.6[e]	145.4±8.52[e]	110.9±10.8[e]

EECA= Ethanolic extract of *Chrysophyllum albidum*, DC= Diabetic Control, Values are Mean± SEM, n=5, a $p<0.001$ when compared to control, b $p<0.001$ when compared to diabetic control, c $p<0.05$ when compared to diabetic control, d $p<0.01$ when compared to diabetic control, e $p<0.001$ when compared to diabetic control

Table 5. Effect of *Chrysophyllum albidum* on serum triglyceride level of alloxan-induced diabetic rats

Dose (mg/kg)	7 days (mg/dL)	14 days (mg/dL)	28 days (mg/dL)
Control	58.I±3.61	57.8±4.32	55.7±3.51
CA 100	59.6±4.57	61.9±5.11	58.5±4.21
CA 200	57.6±5.33	60.6±6.32	58.7±5.23
CA 400	60.1±6.63	58.3±5.56	57.4±4.76
Diabetic Control (DC)	299.9±15.2[a]	300.5±12.3[a]	310.2±15.8[a]
DC +Metformin	100.6±9.61[b]	99.1±8.90[b]	70.9±6.41[b]
DC +EECA 100	237.4±12.7[c]	187.6±11.4[c]	120.3±11.5[c]
DC +EECA 200	160.9±9.32[d]	131.8±10.7[d]	100.7±10.6[c]
DC +EECA 400	101.4±11.6[e]	83.3±7.33[e]	60.8±7.55[e]

EECA= *Ethanolic Extract of Chrysophyllum albidum, DC*= Diabetic Control, Values are Mean± SEM, n=5, [a] p<0.001 when compared to control, [b] p<0.001 when compared to diabetic control, [c] p<0.05 when compared to diabetic control, [d] p<0.01 when compared to diabetic control, [e] p<0.001 when compared to diabetic control

Table 6. Effect of *Chrysophyllum albidum* on total cholesterol level of alloxan- induced diabetic rats

Dose (mg/kg)	7 days (mg/dL)	14 days (mg/dL)	28 days (mg/dL)
Control	90.0±7.32	91.8±8.33	89.6±8.45
CA 100	91.8±7.00	90.2±7.31	87.5±8.90
CA 200	92.0±7.52	88.4±8.62	86.0±7.57
CA 400	90.9±8.61	86.9±7.52	84.9±6.31
Diabetic Control (DC)	355.9±16.1[a]	360.2±13.7[a]	377.9±13.0[a]
DC +Metformin	120.7±11.0[b]	110.0±11.3[b]	90.7±8.32[b]
DC +CA 100	257.8±12.7[c]	209.7±13.8[c]	140.3±10.4[c]
DC +CA 200	200.0±12.0[d]	150.4±11.0[d]	120.4±10.6[c]
DC +CA 400	155.6±10.6[e]	130.8±10.8[e]	90.9±7.52[d]

EECA= *Ethanolic Extract of Chrysophyllum albidum, DC*= Diabetic Control, Values are Mean± SEM, n=5, [a] p<0.001 when compared to control, [b] p<0.001 when compared to diabetic control, [c] p<0.05 when compared to diabetic control, [d] p<0.01 when compared to diabetic control, [e] p<0.001 when compared to diabetic control

Table 7. Effect of *Chrysophyllum albidum* on high density lipoprotein cholesterol level of alloxan- induced diabetic rats

Dose (mg/kg)	7 days (mg/dL)	14 days (mg/dL)	28 days (mg/dL)
Control	42.3±3.32	43.4±3.12	44.6±4.42
CA 100	42.1±3.22	40.1±3.60	40.6±3.70
CA 200	43.8±3.71	40.9±4.21	42.8±3.51
CA 400	43.7±3.60	41.6±3.33	41.9±3.42
Diabetic Control (DC)	10.7±0.27[a]	11.9±0.77[a]	13.4±0.98[a]
DC +Metformin	30.0±2.75[b]	37.7±3.71[b]	40.3±3.56[b]
DC +EECA 100	15.5±1.20[c]	22.0±1.22[c]	27.5±3.33[c]
DC +EECA 200	21.7±2.30[d]	27.5±2.60[d]	34.1±3.71[d]
DC +EECA 400	27.0±2.55[e]	34.0±3.50[e]	42.9±4.57[e]

EECA= *Ethanolic Extract of Chrysophyllum albidum, DC*= Diabetic Control, Values are Mean± SEM, n=5, [a] p<0.001 when compared to control, [b] p<0.001 when compared to diabetic control, [c] p<0.05 when compared to diabetic control, [d] p<0.01 when compared to diabetic control, [e] p<0.001 when compared to diabetic control

Table 8. Effect of *Chrysophyllum albidum* on low density lipoprotein cholesterol level of alloxan- induced diabetic rats

Dose (mg/kg)	7 days (mg/dL)	14 days (mg/dL)	28 days (mg/dL)
Control	36.7±2.33	37.4±2.11	32.0±2.03
CA 100	38.6±2.00	38.6±3.90	35.6±2.70
CA 200	37.9±2.33	35.4±3.10	31.9±3.62
CA 400	35.4±2.41	34.7±2.51	32.6±3.11
Diabetic Control (DC)	229.9±9.88[a]	288.9±10.1[a]	302.6±18.3[a]
DC +Metformin	70.9±5.29[b]	52.5±3.40[b]	36.8±3.67[b]
DC +EECA 100	195.5±9.88[c]	142.0±8.61[c]	140.7±7.66[c]
DC +EECA 200	146.3±7.00[d]	97.8±5.44[c]	66.5±5.43[d]
DC +EECA 400	108.8±7.90[e]	84.5±6.33[e]	50.9±4.33[e]

EECA= *Ethanolic Extract of Chrysophyllum albidum, DC*= Diabetic Control, Values are Mean± SEM, n=5, [a] p<0.001 when compared to control, [b] p<0.001 when compared to diabetic control, [c] p<0.05 when compared to diabetic control, [d] p<0.01 when compared to diabetic control, [e] p<0.001 when compared to diabetic control

Table 9. Effect of *Chrysophyllum albidum* on pancreas oxidative stress markers of alloxan- induced diabetic rats

Dose (mg/kg)	MDA nmole/mg protein	SOD U/mg protein	CAT U/mg protein	GSH µg/mg protein	GPX U/mg protein
Control	0.14±0.02	27.8±3.00	20.6±2.00	14.8±2.12	25.0±3.52
CA 100	0.13±0.05	28.1±2.00	21.7±3.70	15.0±2.63	25.1±3.52
CA 200	0.12±0.07	28.8±2.33	21.9±3.51	15.6±1.51	25.6±2.01
CA 400	0.13±0.02	30.0±3.12	22.8±3.42	15.9±1.21	26.0±3.63
Diabetic Control (DC)	1.21±0.05[a]	6.71±0.12[a]	4.70±0.08[a]	4.91±0.73[a]	7.22±0.76[a]
DC +Metformin	0.20±0.04[b]	24.7±2.32[b]	18.7±2.00[b]	12.5±1.21[b]	23.1±3.72[b]
DC +EECA 100	0.80±0.01[c]	10.8±0.11[c]	7.51±0.33[c]	6.12±0.72[c]	12.6±1.51[c]
DC +EECA 200	0.40±0.05[d]	15.7±1.32[d]	12.6±2.10[d]	8.75±0.57[d]	17.6±0.42[d]
DC +EECA 400	0.23±0.02[e]	22.8±3.11[e]	17.0±1.73[e]	12.0±1.21[e]	23.4±2.00[e]

EECA= *Ethanolic Extract of Chrysophyllum albidum, DC*= Diabetic Control, Values are Mean± SEM, n=5, [a] p<0.001 when compared to control, [b] p<0.001 when compared to diabetic control, [c] p<0.05 when compared to diabetic control, [d] p<0.01 when compared to diabetic control, [e] p<0.001 when compared to diabetic control

Discussion

DM is a metabolic disease associated with impaired glucose and lipid metabolism. It is also associated with impaired beta cell function and oxidative stress (Njolstad *et al*., 2003). The management of DM involves the use of insulin and oral hypoglycemic agents (WHO, 1985). However, some herbal preparations contained active medicinal constituents which are locally used in the management of diabetes (Newman *et al*., 2003). Recently, the world health organization estimated that 80% of people worldwide rely on herbal medicines for part of their primary health care. In Germany, about 600-700 plant based medicines are available and are prescribed by 70% of German physicians (Newman *et al*., 2003). Therefore, the present study evaluated the effect of the ethanolic extract of *C. albidum* stem bark on alloxan - induced diabetic rats. This study observed elevated blood glucose levels in diabetic rats. However, glucose levels were decreased in diabetic rats treated with 100-400 mg/kg of EECA in a dose and time-dependent fashion. This observation shows that EECA has anti-diabetic potential.

Furthermore, lipid profile which is usually altered in diabetic condition is a primary factor for the development of cardiovascular diseases (Abdel-Gayoum *et al*., 2004). In the present study serum levels of TG, TC, and HDL-C were decreased whereas LDL-C levels were increased in diabetic rats. However, the levels of the aforementioned parameters were restored in diabetic rats treated with 100-400 mg/kg of EECA in a dose and time-dependent fashion. This finding shows that EECA contains essential phytochemicals with anti-hyperlipidemic activity.

Studies have shown that DM is associated with oxidative stress characterized by decreased activities of antioxidants and increased lipid peroxidation activity (Dobrian *et al*., 2001; Lipinski, 2001). This study observed that pancreatic activities of SOD, GSH, CAT, and GPX were decreased whereas MDA activities were increased in diabetic rats. This is an evidence of the involvement of oxidative stress in the pathogenesis of DM. However, pancreatic activities of SOD, GSH, CAT, and GPX were increased whereas MDA activities were decreased in 100-400 mg/kg of EECA-treated diabetic rats in a dose and time-dependent fashion.

Alloxan, a β-cytotoxic toxic glucose analogue is commonly used for the development of animal model of type-I diabetes mellitus (IDDM). Alloxan is rapidly taken up by pancreatic β-cells through GLUT2 receptors (Elsner *et al*., 2002) .The observed increases in glucose levels at 7-28 days in diabetic rats could be attributed to alloxan-induced selective inhibition of insulin secretion through specific inhibition of glucokinase, the glucose sensor of the beta cell. It can also be attributed to its ability to induce oxidative stress through free radical generation. Furthermore, glucose levels were reduced in a time-dependent fashion in diabetic rats treated with metformin. Metformin is a standard drug used for the treatment of diabetes. The exact molecular mechanism of its action remains unknown. However, studies have shown that it can inhibits liver gluconeogenesis and facilitate glucose uptake into peripheral tissues, such as striated muscle. It has also been shown to increase insulin sensitivity (Janick, 2017). In this study, EECA might have exhibited similar mechanisms as metformin in decreasing glucose levels in diabetic rats. Also, the effects of EECA could be attributed to its ability to increase insulin production by pancreatic cells. EECA might have decreased the release of glucagon or stimulate direct glycolysis in peripheral tissues or reduce glucose absorption from the gastrointestinal tract (Marriff *et al*., 2005). EECA contains phytochemicals which include terpenoids that are known to reduce glycaemia through many mechanisms which include insulin like activity, inhibition of gluconeogenesis and glycogenolysis (Grover *et al*., 2002). The alterations in pancreatic levels of GSH, CAT, SOD, and MDA in diabetic rats are signs of oxidative stress and lipid peroxidation via the generation of free radicals. Therefore, the dose and time-dependent effects of EECA observed on GSH, CAT, SOD, and MDA in diabetic rats could be attributed to its antioxidant effect through the inhibition of free radical production and its ability to regenerate endogenous antioxidants. EECA contains flavonoids, tannins and phenolics which have antioxidant activities. Studies have also shown that EECA contains high ascorbic acid content which might have contributed to its antioxidant effect observed in the present study. The aforementioned phytochemicals might have protected pancreatic beta cells against oxidative stress, by increasing the endogenous defense capacity of the pancreas to combat oxidative stress and by direct scavenging of free radicals (Sarwar *et al*., 2004).

Conclusions

The oral administration of the ethanolic extract of EECA demonstrated anti-hyperglycemic, anti-hyperlipidemic and anti-oxidative effects on alloxan-induced diabetic rats. This shows that EECA contains essential medicinal substances that could be used as remedy for diabetes. However, further investigation to isolate the active medicinal substance (s) and elucidate the exact mechanism of action is very imperative.

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Conflict of Interest

The authors declare that there are no conflicts of interest related to this article.

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