EFFECTS OF DIFFERENT EXTRACTS OF ROOTS OF *Musa paradisiaca* IN STREPTOZOTOCIN-INDUCED DIABETIC RATS

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Abstract: Plantain (*Musa paradisiaca*) is used for the management of diabetics amongst other diseases. In this study, a comparative antihyperglycemic effect of three solvents (different polarity) extracts of the roots was assessed in streptozotocin (STZ)-induced diabetic rats. Six groups of Albino rats (males) were used. Group I: Normal control rats; Group II: Diabetic control rats; Groups III - V: Diabetic rats treated with 200 mg/kg of Petroleum ether, acetone and ethanol extracts, respectively of *M. paradisiaca*; Group VI: Diabetic rat + 600 µg/kg glibenclamide. All treatments were administered orally for three weeks. A decrease in body weight and increase in fasting blood glucose (FBG) levels, alteration of serum biochemical parameters and antioxidant levels were observed in the diabetic control rats. However, treatment with the extracts for 3 weeks resulted in significant ($p < 0.05$) reduction of FBG level and increased in body weight of the diabetic rats. A significant ($p < 0.05$) improvement was also seen in the lipid profile [total cholesterol (TC), triglycerides (TG), high-density lipoprotein (HDL) and low-density lipoprotein (LDL)] of the diabetic rats treated with extracts compared with the diabetic control rats. Also, the renal/hepatic STZ induced oxidative stress in the diabetic rats were reverted to near normality following oral administration of the extract(s). The results show that the antidiabetic activity of *M. paradisiaca* with the ethanol extract showing better effect among all three extracts used.

Keywords: *Musa paradisiaca*, streptozotocin, antihyperglycemic, glibenclamide, fasting blood glucose

Introduction

Diabetes mellitus (DM) is a long-lasting disorder of metabolism with several etiologies; characterized by prolonged hyperglycemia and disruptions of carbohydrate, lipid and protein metabolisms, resulting from total or relative absence of insulin hormone (Bhutkar and Bhise, 2012). Thus, DM may be due to inadequate production of insulin (child-onset DM or type 1) or from the body's inability to effectively use insulin (adult on-set DM or type 2) (WHO, 2016); the type 2 DM is accountable for over 90% of DM cases. Ineffective production or use of insulin leads to elevated concentration of plasma glucose. Diabetes is also defined by a random glucose level ≥ 200mg/dl (11.1 mmol/L) and a Fasting blood glucose ≥126 mg/dl (7.0 mmol/L) (Mukwaya *et al*., 2016).

DM is well-known as a healthcare emergency triggering weakened functioning of macro and micro organs. The pathological variations depend on the gravity and period of hyperglycemia (Mir *et al*., 2013). The International diabetes federation (IDF) and World health organization (WHO) have predicted an upsurge in the incidence of diabetes, which is projected to get to 552 million by 2030 (Muhtadi *et al*., 2015). DM affects more than 400 million people globally and leads to annual deaths of about 1.6 million. This figure has also been projected to double by 2040 (Mukwaya *et al*., 2016). Thus, the focus by sundry clinicians and researchers around the world is on preclusion and management of DM and its complications (Muhtadi *et al*., 2015).

Plantain (*Musa paradisiaca*) is an essential perennial crop found in the humid/ sub-humid parts of Asia, Africa, Central and South America, and it is typically consumed for its energy yielding food. Reports of its hypoglycemic effects in diabetic animals have been stated (Eleazu *et al.*, 2010; Ojewole and Adewunmi, 2003).

Numerous chemical constituents have been isolated and reported in the literature from *M. paradisiaca* like catecholamines (dopamine, norepinephrine, serotonin), numerous flavonoids and allied compounds (Leucocyanidin, 3-O-glucoside, quercetin and its 3-O-galactoside and 3-O-rhamnosyl glucoside). Acyl steryl glycosides like sitoindoside-I to sitoindoside-IV and steryl glycosides like sitosterol gentiobioside, myo-inosityl-β-D-glucoside and sitosterol (Lakshmi *et al.*, 2014).

Several parts of the plant have been utilized for different medicinal purposes. In a study by Lakshmi *et al* (2014) to assess the antidiabetic potential of *M. paradisiaca* on Streptozotocin-induced diabetic rats, they found the ripe fruit peel and leaves to exhibit anti-diabetic effect. Similarly, its anti-ulcerogenic (Ikpeazu *et al*., 2017), anti-microbial (Kapadia *et al*., 2015) antioxidant (Shodehinde and Oboh, 2013), antidiabetic and hepatic dysfunction (Ojewole and Adewunmi, 2003; Eleazu and Okafor, 2015), antimicrobial (Amutha and Selvakumari, 2016) activities, as well as its wound healing and hepato-protective properties (Nirmala *et al*., 2012; Agarwal *et al*., 2009) and LD_{50} of its roots (Emordi *et al.*, 2014) have been reported. Also *M. paradisiaca* is used for the treatment of dysentery, spur, gout, uremia, nephritis and cardiac disease (Lakshmi *et al.*, 2014). Amongst all the possible uses of the plant for management and the treatment of diseases, very little report is found in the literature on the antidiabetic activity of its roots. Therefore, this study was aimed at comparatively evaluating the antihyperglycemic activity of three solvents (different polarity) extracts of the roots in streptozotocin (STZ)-induced diabetic rats.

Materials and Methods

Drugs and chemicals

Glibenclamide and streptozotocin (STZ) were obtained from (Sigma-Aldrich Co. USA). All other solvents/ reagents of analytical ranking were used in the experiments.

Collection, identification and preparation of plant material

Roots of *M. paradisiaca* were collected from the main campus of the Delta State University, Abraka and identified at the Department of Botany of the University. They were washed, cut into pieces and air dried for two weeks, and powdered with mortar and pestle. The powder (50 g) was cold macerated with 200 mL of ethanol, filtered through WhatMan # 1 filtered paper, and rotary evaporated. This procedure was repeated using acetone and then petroleum ether. The resultant crude extracts were used for the study.

Induction of diabetes

Diabetes was induced by a single intraperitoneal injection of streptozotocin (60 mg/kg) dissolved in citrate buffer (pH 4.5) in overnight fasted rats. Fasting Blood glucose (FBG) level was estimated after 72 h of STZ administration. Rats showing fasting blood glucose (FBG) ≥ 250 mg/dl were considered diabetic and used for the study.

Experimental design

Thirty six male rats (150–180 g) were used and divided into six groups (n = 6) as follows:

Group-I: Normal control rats.

Group-II: Diabetic control rats.

Group-III: Diabetic rat + 200 mg/kg Pet. ether roots extract of *M. paradisiaca*.

Group-IV: Diabetic rat + 200 mg/kg Acetone roots extract of *M. paradisiaca*.

Group-V: Diabetic rat + 200 mg/kg Ethanol roots extract of *M. paradisiaca*.

Group-VI: Diabetic rat + 600 µg/kg glibenclamide.

Treatments were carried out for 21 days. The choice of 200mg/kg dosage of *M. paradisiaca* roots extract was informed by the results of earlier reports on the LD_{50} of its roots (Emordi *et al.*, 2014), found to be 18.84 g/Kg b.wt. Fasting blood glucose level was taken in the blood from their tail vein before treating (day 0) at steady intervals of 7th, 14th, and 21st days, correspondingly in all groups and determined by methods of Trinder *et al.* (1969). Also, their body weights were determined regularly. On 22nd day of experiment, final weights of the animals were taken and they were sacrificed by decapitation after overnight fasting. Blood samples (serum) and organs (liver and kidney) were obtained and used for the biochemical assays.

Biochemical assays

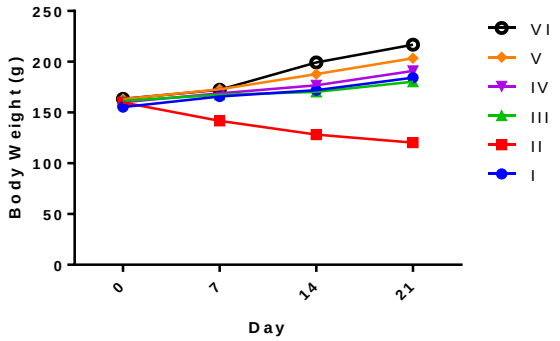
The Biochemical parameters were determined using standard protocols: total cholesterol (Lorke, 1983), triglycerides (Frode and Medeiros, 2008), HDLcholesterol (Kunst *et al*., 1984) and LDL-cholesterol (Kunst *et al*., 1984), Lipid peroxidation (Buege and Aust, 1978), Catalase (Aebi, 1974), Superoxide dismutase (McCord and Fridovich, 1969). While [Alaninine aminotransferase (ALT), alkaline phosphatase (ALP), aspartate aminotransferase (AST)] (King, 1965a, 1965b), total proteins (Lowry *et al.*, 1951), urea (Natelson *et al.*, 1951) and creatinine (Brod and Sirota, 1948).

Statistical analysis

Data obtained were subjected to analysis of variance (ANOVA) and A p-value of <0.05 was statistically considered significant in comparison.

Results and Discussion

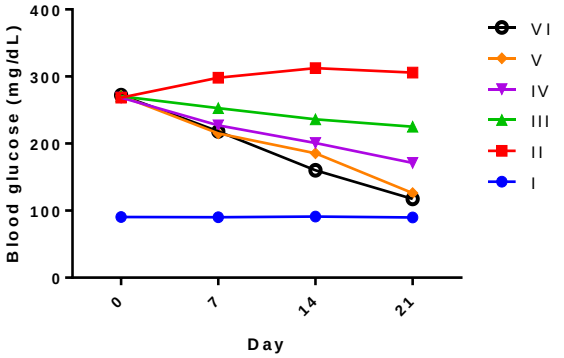
Shown in Fig. 1 are the results of the effects of roots extracts of *M. paradisiaca* on body weights of STZ-induced diabetic rats. A significant ($p < 0.05$) steady decrease in weight was seen in the diabetic control group relative to the normal control group. On the other hand, an appreciable and significant ($p < 0.05$) increase in weights were observed in the normal control group, the standard control group and the extract treated groups at day 21 when compared with day 0 of the experiment.



*Values are stated as mean ± SD (n=6)

Where: I=normal control rats; II= diabetic control rats; III= diabetic rat + 200 mg/kg Pet. ether extract of *M. paradisiaca*; IV= diabetic rat + 200 mg/kg acetone extract of *M. paradisiaca*; V= diabetic rat + 200 mg/kg ethanol extract of *M. paradisiaca*; VI= diabetic rat + 600 µg/kg glibenclamide

Fig. 1: Effects of different roots extracts of *M. paradisiaca* on body weights of STZ-induced diabetic rats



*Values are stated as mean ± SD (n=6)

Where: I=normal control rats; II= diabetic control rats; III= diabetic rat + 200 mg/kg Pet. ether extract of *M. paradisiaca*; IV= diabetic rat + 200 mg/kg acetone extract of *M. paradisiaca*; V= diabetic rat + 200 mg/kg ethanol extract of *M. paradisiaca*; VI= diabetic rat + 600 µg/kg glibenclamide

Fig. 2: Effects of different roots extracts of *M. paradisiaca* on fasting blood glucose levels of STZ-induced diabetic rats

The results for the effects of different roots extracts of *M. paradisiaca* on fasting blood glucose (FBG) levels of STZ-induced diabetic rats are shown in Fig. 2. After seven days of treatment with either extracts of the plant or the reference drug, significant ($p < 0.05$) decrease in FBG were observed. The decrease in FBG in these groups (III – VI) was also seen after 14 days of treatment, with even further decrease observed after 21 days of treatment. Comparatively, the highest decrease in FBG level was noticed in the ethanol extract treated group among the plant extracts. However, a significant ($p < 0.05$) increase in FBG level was observed in the diabetic control group in week 1 and 2 when compared with week 0 of the experiment.

The Lipid profile results of STZ-induced diabetic rats treated for 21 days with root extracts of *M. paradisiaca* are shown in Table 1. Significantly ($p < 0.05$) higher values were observed in the total cholesterol, triacylglycerol and LDL of the diabetic control group when compared with the normal control ones. On the other hand, significantly lower ($p < 0.05$) value of HDL was seen in the same diabetic control group, relative to the normal control group. Contrary to the lipid profile values obtained for the diabetic control, there was noticeable improvement in the lipid profile parameters in the roots extracts treated groups as well as the reference drug treated group. Among the extracts treated groups, the best values closed to the normal control were seen in the ethanol extract treated group.

Table 1: Effects of different roots extracts of *M. paradisiaca* on lipid profile of STZ-induced diabetic rats after 21 days

Parameter	I	II	III	IV	V	VI
TC(mg/dL)	70.26±4.50^{a}	128.90±3.75^{b}	118.29±3.51^{c}	102.13±6.00^{d}	87.02±5.95^{e}	75.11±2.63^{a}
TG(mg/dL)	70.89±2.75^{a}	191.17±9.82^{b}	161.47±7.30^{c}	124.61±5.22^{d}	80.33±6.67^{a}	71.10±2.40^{a}
HDL(mg/dL)	39.98±3.26^{a}	17.18±1.28^{b}	19.76±1.48^{b}	24.68±1.39^{c}	29.64±2.16^{c}	33.27±1.97^{a}
LDL(mg/dL)	16.10±2.96^{a}	73.49±5.25^{b}	66.24±4.74^{b}	52.53±6.41^{c}	41.31±7.97^{d}	27.62±1.88^{e}

*Values are stated as mean ± SD (n=6). **Across rows, values with dissimilar superscripts differs statistically (P<0.05).
I=normal control rats; II= diabetic control rats; III= diabetic rat + 200 mg/kg Pet. ether extract of *M. paradisiaca*; IV= diabetic rat + 200 mg/kg acetone extract of *M. paradisiaca*; V= diabetic rat + 200 mg/kg ethanol extract of *M. paradisiaca*; VI= diabetic rat + 600 µg/kg glibenclamide

Table 2: Effects of different roots extracts of *M. paradisiaca* on liver function parameters of STZ-induced diabetic rats after 21 days

Parameter	I	II	III	IV	V	VI
ALP(UI/L)	89.42±3.46^{a}	207.12±3.53^{b}	174.25±6.84^{c}	123.43±4.86^{d}	98.47±3.77^{e}	91.60±1.18^{ae}
AST(UI/L)	42.15±1.83^{a}	102.17±5.82^{b}	86.09±3.30^{c}	59.53±1.89^{d}	56.23±2.46^{de}	50.47±1.53^{e}
ALT(UI/L)	32.66±1.86^{a}	96.24±4.29^{b}	82.89±4.37^{c}	57.31±3.21^{d}	38.63±3.38^{a}	33.73±2.09^{a}
Total Protein(mg/dL)	7.90±0.49^{a}	6.51±0.82^{a}	7.22±0.34^{a}	7.41±0.36^{a}	7.72±0.48^{a}	7.73±0.51^{a}

*Values are stated as mean ± SD (n=6). **Across rows, values with dissimilar superscripts differs statistically (P<0.05)
I=normal control rats; II= diabetic control rats; III= diabetic rat + 200 mg/kg Pet. ether extract of *M. paradisiaca*; IV= diabetic rat + 200 mg/kg acetone extract of *M. paradisiaca*; V= diabetic rat + 200 mg/kg ethanol extract of *M. paradisiaca*; VI= diabetic rat + 600 µg/kg glibenclamide

Results for the liver function parameters of STZ-induced diabetic rats after 21 days treatment with different roots extracts of *M. paradisiaca* are shown in Table 2. There was no significant difference in the total protein parameters among the groups (I – VI). However, significantly ($p < 0.05$) higher values were seen in the ALP, AST and ALT parameters for the diabetic control rats when compared with the normal control group. Also, values close to the normal control group were observed in the ethanol and reference drug treated groups. Thus, treatment with either extract or the reference drug prevented the STZ induced increase in the liver marker enzymes.

The results of effects of different roots extracts of *M. paradisiaca* on kidney function parameters of STZ-induced diabetic rats after 21 days treatment are shown in Table 3. Significantly ($p <0.05$) higher values for Creatinine and Urea were observed in the diabetic control group relative to the normal control rats. However, treatment with either extracts or the reference drug for 21 days caused a reversal of these parameters values to near normal level.

Table 3: Effects of Different Roots Extracts of *M. paradisiaca* on Kidney Function Parameters of STZ-Induced Diabetic Rats after 21 days

Parameter	I	II	III	IV	V	VI
Creatinine	0.65±0.01^{a}	0.93±0.01^{b}	0.83±0.01^{c}	0.74±0.02^{d}	0.72±0.01^{de}	0.68±0.01^{a}
Urea	3.10±0.43^{a}	8.24±0.50^{b}	6.15±0.48^{c}	4.66±0.42^{d}	3.40±0.19^{a}	3.26±0.28^{a}

*Values are stated as mean ± SD (n=6). **Across rows, values with dissimilar superscripts differs statistically (P<0.05)
I=normal control rats; II= diabetic control rats; III= diabetic rat + 200 mg/kg Pet. ether extract of *M. paradisiaca*; IV= diabetic rat + 200 mg/kg acetone extract of *M. paradisiaca*; V= diabetic rat + 200 mg/kg ethanol extract of *M. paradisiaca*; VI= diabetic rat + 600 µg/kg glibenclamide.

Table 4 (a): Effects of Different Roots Extracts of *M. paradisiaca* on Liver markers of oxidative stress in STZ-induced Diabetic Rats after 21 days

Parameter	I	II	III	IV	V	VI
LPO(nM/mg protein)	3.44±0.25^{a}	8.13±0.68^{b}	6.10±0.61^{c}	5.43±0.62^{cd}	4.82±0.57^{d}	3.96±0.69^{ad}
SOD(units /mg protein)	29.72±1.56^{a}	13.91±0.48^{b}	14.43±1.23^{b}	19.10±1.14^{c}	25.45±2.01^{a}	28.22±1.13^{a}
CAT(units/mg protein)	17.02±1.00^{a}	7.95±0.67^{b}	10.40±0.54^{c}	12.67±0.65^{d}	14.88±0.80^{ad}	16.12±0.90^{a}

*Values are stated as mean ± SD (n=6). **Across rows, values with dissimilar superscripts differs statistically (P<0.05)
I=normal control rats; II= diabetic control rats; III= diabetic rat + 200 mg/kg Pet. ether extract of *M. paradisiaca*; IV= diabetic rat + 200 mg/kg acetone extract of *M. paradisiaca*; V= diabetic rat + 200 mg/kg ethanol extract of *M. paradisiaca*; VI= diabetic rat + 600 µg/kg glibenclamide

Table 4 (b): Effects of Different Roots Extracts of *M. paradisiaca* on Kidney markers of oxidative stress in STZ-induced Diabetic Rats after 21 days

Parameter	I	II	III	IV	V	VI
LPO(nM/mg protein)	2.82±0.41^{a}	6.61±0.56^{b}	5.20±0.41^{c}	4.17±0.36^{d}	3.42±0.48^{ad}	3.08±0.59^{ad}
SOD(units /mg protein)	26.90±1.02^{a}	12.60±0.85^{b}	11.77±1.21^{b}	16.50±0.86^{c}	21.22±0.75^{d}	25.18±0.72^{a}
CAT(units/mg protein)	14.15±1.14^{a}	6.18±0.75^{b}	7.36±0.73^{c}	9.53±1.01^{c}	11.41±0.62^{d}	13.47±0.50^{a}

*Values are stated as mean ± SD (n=6). **Across rows, values with dissimilar superscripts differs statistically (P<0.05)
I=normal control rats; II= diabetic control rats; III= diabetic rat + 200 mg/kg Pet. ether extract of *M. paradisiaca*; IV= diabetic rat + 200 mg/kg acetone extract of *M. paradisiaca*; V= diabetic rat + 200 mg/kg ethanol extract of *M. paradisiaca*; VI= diabetic rat + 600 µg/kg glibenclamide

Shown in Table 4 are results for the effects of treatment of STZ-induced diabetic rats with different roots extracts of *M. paradisiaca* on liver and kidney markers of oxidative stress after 21 days. A significantly ($p < 0.05$) higher LPO values were noticed in the diabetic control group when compared to the normal control group for both organs. While significantly ($p < 0.05$) lower values for SOD and CAT were seen in the diabetic control group relative to the normal control rats. However, a reversal to near normal of the STZ induced increase in LPO and decrease in SOD and CAT were seen in the extract treated groups and reference drug treated group when compared with the diabetic control group.

Diabetes mellitus is an endocrine disorder characterized by a metabolic condition that affects carbohydrate, protein and fat metabolism intricate by multi-organ weakening as the disease progresses (Gao *et al.,* 2012). Medicinal plant, as a basis of alternative medicine has potentiality for new drug discovery due to diversity of its active compounds (Sasidharan *et al.,* 2011). Although the medicinal value of plantain (*Musa paradisiaca*) for the management of diabetics and other diseases has been widely reported. However, very little information is found in the literature on the antidiabetic activity of its roots. In this study, the comparative antihyperglycemic effects of three solvents (different polarity) roots extracts were assessed in streptozotocin (STZ)-induced diabetic rats.

Streptozotocin is generally used to induce experimental diabetes, which normally involves lipid disturbance and weight lost (Dzeufiet *et al.,* 2006). During the development of DM, a reduction in body weight happens due to lack of energy and the cellular catabolic progression characterized by glycogenolysis, proteolysis and lipolysis. In this study, the diabetic rats demonstrated a significant reduction in body weight gain when equated with the normal control rats during the experimental period. The weight reduction might be due to protein wasting occasioned by unavailability of carbohydrates as source of energy initiated by the want of insulin following STZ injection (Gao *et al.,* 2012). However, the administration of roots extracts of *M. paradisiaca* caused significant increase in body weight of the diabetic rats. The improvement of body weight may be due to decrease in protein breakdown and peripheral glucose using properties of the extracts (Neto *et al*., 2013).

The efficacy of antidiabetic agents for diabetes management is usually adjudged with measurement of body glucose levels. During DM, large expanse of glucose amasses and is intensively used by insulin-free cells through glycolysis and the Krebs cycle, thereby increasing the work of mitochondria electron transport chain with extra superoxide anion radical's formation (Kahn, 2014). In this study, STZ injection led to steady increase in FBG level of the diabetic rats. However, continuous treatment of the diabetic rats for 21 days led to significant reduction in FBG level of the rats. The decrease in FBG became obvious after 14 days of treatment, with even further decrease observed after 21 days of treatment. Comparatively, the highest decrease in FBG was noticed in the ethanol extract treated group among the plant extracts. The hypoglycemic result seen in this study supports the reports of Mallick *et al*., 2006 and Mallick *et al*., 2007. Also, Kumar *et al*. (2012) reported a dose dependent reduction of blood glucose in diabetic and normal mice following treatment with methanolic extracts of fruit of *M. paradisiaca.* Several phytochemicals (alkaloids, flavonoids, polysaccharides, glycosides/sterosids/terpenoids, saponins and proteins) are known to possess antidiabetic action (Lamba *et al.,* 2000). And the presence of these phytoconstituents has been reported for *M. paradisiaca* (Lakshmi *et al.,* 2014; Akpabio *et al.,* 2012; Akpuaka and Ezem, 2011). Thus, the antidiabetic activity of the extracts may be due to the actions of the phytoconstituents.

It is well-known that dyslipidemia which leads to vascular complications is usually associated with diabetes mellitus. This dyslipidemia may be due to deficiency of lipoprotein lipase activity which contributes to significant rise of triglycerides in the diabetes. The lipid profile irregularities in diabetes include raised levels of Total Cholesterol (TC), Low Density Lipoprotein (LDL), Triglycerides (TG), and decreased High Density Lipoprotein (HDL) levels (Peng *et al.,* 2017; Yang and Kang, 2018). In this study, significantly higher values of total cholesterol, triacylglycerol and LDL were observed for the STZ-induced diabetic rats when compared with the normal control group, while lower value of HDL was noticed in the same diabetic control relative to the normal control group. This observation agrees with the report of Mitra *et al.,* 1995 and Reitman and Frankel, 1975 that in STZ-induced diabetes, the rise in blood glucose is generally complemented by a decrease in plasma HDL and an increase in cholesterol, LDL and triglycerides. Contrary to the lipid profile values obtained for the diabetic control, there was noticeable improvement in the lipid profile parameters in the roots extracts treated groups as well as the reference drug treated group. Among the extracts treated groups, the best values closed to the normal control were seen in the ethanol extract treated group. This observation is in agreement with previous reports by Mallick *et al*. (2007) and Lakshmi *et al.* (2014).

An increase in biomarker enzymes (alkaline phosphatase, alanine aminotransferase and aspartate aminotransferase) in the bloodstream is a sign of hepatocellular damage showing that these enzymes have escaped into the bloodstream (Jaeschkle *et al.,* 2002). The AST enzyme is located in a diversity of tissues like the liver, brain and heart, while the ALT is typically found at elevated proportions in the liver. Whenever it is found in the blood, it is generally due to liver damage (Zhang *et al*., 2015). In this study, higher values of the liver marker enzymes (ALP, AST and ALT) were seen in the diabetic control rats when compared with the normal control group. However, treatment of the STZ induced diabetic rats for 21 days led to normalization of levels of the marker enzymes. Thus, treatment with either extract or the reference drug brought the levels of the enzymes close to the normal control group with the ethanol and reference drug treated groups displaying the best hepatoprotective effects overall.

Serum total protein suggests the synthetic role of the liver (Braunwald *et al*., 2001). In this study, the levels of serum total protein were generally not significant among all experimental group. Thus, implying that the extract did not affect the protein synthetic capability of the liver.

STZ-induced diabetes is normally characterized with increase level of the serum creatinine and urea which is considered as important renal markers of dysfunction. Urea and creatinine are byproducts of body metabolism, commonly excreted in kidney (Nain *et al.,* 2012). In this study, significantly higher values for Creatinine and Urea were observed in the diabetic control rats relative to the normal control rats. However, treatment with either extracts or the reference drug for 21 days caused a reversal of the parameter values to near normal level.

STZ-induced diabetes was characterized by augmented production of reactive oxygen species (ROS), involved in etiology of some diabetic problems like hepatic damage and diabetic nephropathy (Cheng *et al.,* 2013). Oxidative stress can result from insufficient glycemic control with abnormal rise in glucose levels. Clinical evidence has shown that diabetes is directly correlated with oxidative stress, leading to amplified generation of free radicals or decrease in the antioxidant defense systems (Susztak *et al.,* 2006). MDA is

believed to be an effective biomarker of the process of lipid peroxidation. In this experiment, a significantly higher LPO values were noticed in the diabetic control group when compared to the normal control group for both organs. The raised lipid peroxidation seen in the diabetic rats may be ascribed to increased production of ROS, leading to oxidative stress (Ilhan *et al*., 2001). Also, this observation is consistent with previous findings that revealed raised plasma and tissue MDA levels in STZ-induced diabetic rats (Nakhaee *et al*., 2009). Pancreatic β-cells are extremely prone to damage and oxidative stress as they express small antioxidant enzymes levels. STZ may harm pancreatic tissue by imposition of oxidative stress, with subsequent induction of apoptosis in the pancreatic cells (Manna *et al*., 2009). Treatment of the STZ-induced diabetic rats with roots extracts of *M. paradisiaca* for 21 days led to a reversal of the STZ induced lipid peroxidation. The diminished level of LPO noticed in the treated diabetic rats denotes melioration in defense mechanisms of the enzymatic as well as non-enzymatic antioxidants (Saddala *et al*., 2013). Also in this study, significantly lower values for SOD and CAT were seen in the diabetic control rats relative to the normal control rats. However, a reversal to near normal of the STZ induced decrease in SOD and CAT were seen in the extract treated groups and reference drug treated group when compared with the diabetic control group. This observation is in concord with earlier reported antioxidant ability of *M. paradisiaca* (Kalita *et al.,* 2016).

Comparatively, the ethanol extracts exhibited better antidiabetic activity among the extracts used for this experiment. This is in concord with earlier report by Lakshmi *et al.* (2014), who reported that the ethanolic extract of *M. paradisiaca* showed hopeful antidiabetic effect in STZ model.

Conclusion

The study shows that the antidiabetic activity of the roots extracts of *M. paradisiaca* in STZ induced diabetic rats with the ethanol extract demonstrating more antidiabetic activity than the rest extracts. Thus, corroborating the earlier reports on the antidiabetic effects of the plant.

Conflict of Interest

Author declares that there is no conflict of interest reported in this work.

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