Hypoglycemic Effectof *Manniophyton Fulvum* Aqueous Root Extract on Streptozotocin-Induced HyperglycemicWistar Rats

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Abstract

This study investigated the hypoglycemic effect of *M. fulvum* on streptozotocin (STZ) – induced hyperglycemia in Wistar rats. The oxidative damage in the blood, liver, pancreas and kidney cells, hepatic enzyme activities and lipid profile of the Wistar rats were also ascertained. Rats were exposed to STZ alone at 160 mg/kg body weight for one week to induced hyperglycemia before treatment with *M. fulvum* at 83 and 113 mg/kg for 28 consecutive days. Results showed significant elevation in the levels of blood glucose level, amylase activity, serum lipid profile and serum renal markers (total protein, urea and creatinine) in the hyperglycemic rats. Moreover, streptozotocin – induced hyperglycemic rats showed significantly ($p < 0.05$) reduced antioxidant status (reduced levels of superoxide dismutase and catalase activities as well as decreased in reduced glutathione and increased level of malondialdehide). *M. fulvum* was able to demonstrate marked hypoglycemic effect and ameliorate the above mentioned biochemical markers. Streptozotocin – induced rats had significant histopathological damages found in the pancreas when compared with the control. The present study shows that *M. fulvum*possesses significant hypoglycemic, antihyperlipidemic and antioxidant effects in streptozotocin-induced hyperglycemic rats due to its ability to effectively reduced or ameliorate the increase in blood glucose levels, lipid profile and oxidative damages.

Keywords: *M. fulvum*, streptozotocin,hypoglycemic,hyperglycemic,antihyperlipidemic, antioxidant

1. Introduction

Diabetes mellitus developeddue to metabolic imbalance which is non-physiological (Machha et al., 2007). It is characterized by relative or absolute deficiencies in insulin secretion and/or insulin action associated with chronic hyperglycemia and disturbances of carbohydrate, lipid and protein metabolism (Duckworth, 2001). It is known worldwide (Elizza et al., 2009) that diabetic mellitus affect about 7% of the adult populations (Babu et al., 2013) and it is responsible for many deaths globally (Devi et al., 2012). The prevalence of diabetes cases is increasing worldwide, especially in the developing countries (Shaw et al., 2010). Diabetes mellitus is known to cause hyperglycemia that may result in the damage to the eyes, kidneys, blood vessels, nerves and may adversely affect physical, social and psychologicalwell-beingof an individual. Some symptoms associated with diabetes mellitus are blurring of vision, weight loss, polyuria, polyphagia and polydipsia. Other serious symptoms of hyperglycemia include non – hyperosmolar coma and ketoacidosis if left untreated (Devi et al. 2012).

Researchers all over the world are currentlyworking on replacing synthetic anti-diabetic drugs with natural antioxidants from plant materials found in our environment. This may be as a results of new knowledge that diabetes mellitus is associated with the increased free radical's formation, decreased antioxidant potential etc. (Naziroğlu and Butterworth, 2005). Research work have also shown that plants contain a large variety of substances that possess antioxidant properties (Chanwitheesuk et al., 2005; Bacanli et al., 2017; Adedara et al., 2017). This may lead to the formation of advanced glycated end products (AGEs) and other diabetic complications associated with oxidative stress (Rahimi et al., 2005).

M. fulvum is one of the important herbs among the common people and local traditional medicine practitioners in African region (Agbaire et al., 2013). It belongs to the family euphorbiacea(Ojieh et al., 2013).In African traditional medicine the root, stem, bark and leaf are

credited with analgesic properties, and are used to treat diarrhea, stomach ache, cough, bronchitis, oxidative stress and inflammation (Nia et al., 2005). The red stem sap is credited with hemostatic properties, while the leaf sap is used against ear problems (Nia et al., 2005). It is also known as a good treatment option for dysentery and dysmenorrhea (Bouquet et al., 1969; Bouquet et al., 1974). The leaf of *M. fulvum* is credited with antioxidant and antidiarrheal properties (Ezeigbo et al., 2010; Ojieh et al., 2013).

In the present study, the hypoglycemic effect of *M. fulvum* on streptozotocin – induced hyperglycemia, oxidative damage in the blood, liver and kidney cells, hepatic enzyme activities and lipid profile of Wistar rats were evaluated. To evaluate the oxidative damages, the markers such as SOD, CAT activities as well as GSH and MDA levels; hepatic enzymes AST, ALT and ALP activities; serum lipid profile such as HDL – C, LDL – C, total cholesterol, triglyceride were determined to investigated the effect of *M. fulvum* on streptozotocin – induced rats.

2. Materials and Methods

2.1. Chemicals

Streptozotocin, reduced glutathione, bovine serum albumin, glutathione, epinephrine, 5',5'-dithio-bis-2-nitrobenzoic acid (DNTB), bovine serum albumin (BSA), trichloroacetic acid (TCA), thiobarbituric acid (TBA) and hydrogen peroxidewere obtained from Sigma-Aldrich Chemical (St. Louis, MO). Sulfosalicylic acid, di-sodium hydrogen phosphate, sodium di-hydrogen phosphate, and sodium hydroxide were purchased from E. Merck Limited. Total cholesterol, triglycerides, low density lipoprotein (LDL-C), high density lipoprotein (HDL-C) cholesterol levels, aspartate amino transferase, alanine amino transferase, alkaline phosphatase, bilirubin (total and direct), creatinine, urea, and total proteins were estimated from the serum

using RANDOX kits. All other reagents were of highest analytical grade and were purchased from the British Drug Houses (Poole, Dorset, UK).

2.2. Animal Husbandry

Fifty adult male Wistar rats (8 weeks old; 130 – 150g) obtained from the Department of Biochemistry, Faculty of Science, University of Port Harcourt, Rivers State, Nigeria were used for the present study. The animals were housed in plastic cages placed in a well-ventilated vivarium and subjected to natural photoperiod of 12-h light:12-h dark cycle. They were fed with rat chow and given drinking water and libitum for two weeks before the commencement of the experiment. All the animals received humane care according to the conditions stated in the 'Guide for the Care and Use of Laboratory Animals' prepared by the National Academy of Science (NAS) and published by the National Institute of Health. The experimental protocols were performed after approval by the University of Port Harcourt Ethical Committee.

2.3. Experimental Design

2.3.1. Streptozotocin-induced Hyperglycemia Model

Wistar rats were kept in fasting condition for 12 hours, thereafter hyperglycemia was induced by intraperitoneal injection of STZ at 60 mg/kg in freshly prepared PBS, in 0.01 M citrate buffer with a pH of 4.3. (Cumaoğlu et al., 2011; Sabahi et al., 2016). After one week, blood samples were obtained by tail prick, and hyperglycemia was confirmed by fasting (8 hours) blood glucose value of 250 mg/dL higher using glucometer (Plusmed).

2.4. Animals Treatment

The rats were randomly divided to five groups of 8 rats each as follows:

Group I (Control): Rats received normal drinking water and feed for 35 consecutive days.

Group II (MF): Rats were orally treated with *M. fulvum*(MF) at the dose of 113 mg/kg body weight, water and feed.

Group III (STZ): Rats were givenstreptozotocin(STZ)intraperitoneal injectionalone at a dose of 60 mg/kg body weight, water and feed.

Group IV (STZ + MF 1): Rats were co-administered with streptozotocin (STZ) intraperitoneal injectionat a dose of 60 mg/kg body weight and *M. fulvum*orally at the dose of 85 mg/kg body weight, water and feed.

Group V (STZ + MF 2): Rats were co-administered with streptozotocin(STZ) intraperitoneal injectionat a dose of 60 mg/kg body weightand *M. fulvum*orallyat the dose of 113 mg/kg body weight, water and feed.

The doses of STZ (60 mg/kg) and MF (85 and 113 mg/kg) used in the present study were chosen based on the results from the pilot study in our laboratory.

2.5. Tissues Sampling

After the induction of diabetes and twenty-four hours after the 28 days' treatment, the final body weight of each rats were recorded. Blood samples were collected and kept in plain blood test tubes prior to the animal sacrifice by cervical dislocation. The collected blood samples were centrifuged at 3000 g for 10 min to obtain the serum, which were thereafter stored frozen at -20^{0}C before the biochemical assays. The pancreatic tissues were excised, weighed and processed for histological analyses after being washed with ice-cold phosphate-buffered saline.

2.6. Biochemical Assays

The plasma glucose concentration was determined using the One Touch™ glucose strips and glucometer. The serum activities of AST, ALP, ALT and amylase was determined using RANDOX test kits protocol (Randox laboratories, Crumlin, England). Serum levels of

conjugated bilirubin, unconjugated bilirubin, total bilirubin, HL – Cholesterol, LL – Cholesterol, total cholesterol, triglyceride, creatinine, urea was also determined using RANDOX test kits protocol (Randox laboratories, Crumlin, England).

2.7. Oxidative Stress Assays

Reduced glutathione (GSH) was estimated by the method of Ellmans (Ellman, 1959). Malondialdehide (MAD) was determined according to the method described by Ohkawa et al. (1979). Catalase was estimated according to the method of Sinha (1972) and superoxide dismutase (SOD) was estimated according to the method of Marklund and Marklund, 1974.

2.8. Histological Examination

The pancreas collected from 3 rats were fixed in 10% formalin – saline (PBS) solution for twenty – eight (28) at 4^0C overnight and before embedded in paraffin the following day according to the method of Baker and Silverton, (1998). In brief, the fixed pancreas tissues were dehydrated in graded series of alcohol concentrations, cleared by xylene, impregnated in molten paraffin wax and embedded in paraffin wax. The embedded tissues were subsequently cut to produce 5-µm sections using a microtome, fixed on the slides, and stained with hematoxylin and eosin (H&E). Finally, the slides were viewed using the light microscope and histopathological changes were observed and recorded at X 200 magnification.

2.9. Statistical analysis

Statistical analyses were carried out using one-way analysis of variance (ANOVA) to compare the experimental groups followed by Bonferroni's post-hoc test using GRAPHPAD PRISM 5

software (Version 4; GraphPad Software, La Jolla, California, USA). Values of $p < 0.05$ were considered significant.

3. Results

3.1. Effect of *M. fulvum* aqueous root extract on fasting blood glucose level of streptozotocin-induced HyperglycemicWistar rats

The effects of *M. fulvum* on fasting blood glucose level in streptozotocin-induced hyperglycemic ratsare presented in **Table 1**. There was no significant ($p \leq 0.05$) difference in the blood glucose level before hyperglycemia induction. However, there was significant ($p \leq 0.05$) difference in in fasting blood glucose level in STZ alone, STZ + MF 1 and STZ + MF 2 groups when compared with the control. Furthermore, there was significant ($p \leq 0.05$) difference in fasting blood glucose level in STZ alone group when compared with the control. *M. fulvum* treatment significantly ($p \leq 0.05$) reduced fasting blood glucose level in the treated group i.e. STZ + MF 1 and STZ + MF 2 groups. There was also significant ($p \leq 0.05$) difference in fasting blood glucose level in STZ + MF 1 and STZ + MF 2 groups when compared with the STZ alone group.

Table 1. Effect of *M. fulvum* aqueous root extract on fasting blood glucose level (mmol/L) of streptozotocin-induced hyperglycemicWistar rats

Groups	Before Induction	After Induction	After Treatment
Control	4.84±1.34	5.19±1.11	5.16±1.45
MF alone	5.05±1.21	5.07±1.46	4.84±1.34
STZ alone	4.63±1.53	7.25±1.19[a]	8.87±1.12 [a]
STZ + MF 1	4.84±1.34	7.14±1.09[a,b]	6.58±1.39[a,b]

STZ + MF 2	4.96±1.22	7.27±1.17[a,b]	5.83±1.16 [b]

STZ = streptozotocin, MF = M. fulvum. The data are expressed as Mean ± SD; (n = 5). "a" significantly different from the control at $p \leq 0.05$, while "b" significantly different from the STZ alone at $p \leq 0.05$.

3.2. Effect of *M. fulvum* aqueous root extract on amylase activity of streptozotocin-induced hyperglycemicWistar rats

The effects of *M. fulvum* on amylase activity instreptozotocin-induced hyperglycemic ratsare presented in **Figure 1**. There was significant ($p \leq 0.05$) difference in amylase activity in STZ alone when compared to the control. Also, STZ + MF 1 and STZ + MF 2 groups were significantly ($p \leq 0.05$) different when compared with the STZ alone group.

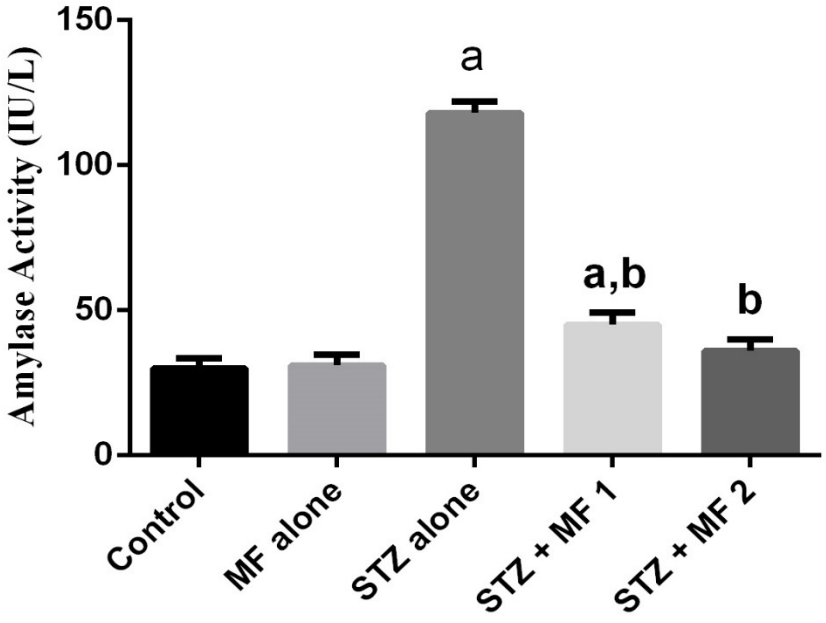

Figure 1: The effect of *M. fulvum* on streptozotocin – inducedhyperglycemicWistar rats on amylase activity in serum of rat. streptozotocin, STZ; *M. fulvum,* MF; STZ (160 mg/kg body weight); MF 1, (83mg/kg body weight); MF 2, (113mg/kg body weight). The data areexpressed

as mean ± S.D. for 5 rats per group. a: Values differ significantly from control ($p \leq 0.05$). b: Values differ significantly from STZ alone at $p \leq 0.05$.

3.3. Effect of *M. fulvum* aqueous root extract on AST, ALP and ALT activities of streptozotocin-induced hyperglycemicWistar rats

The effects of *M. fulvum* on liver function markers (AST, ALP andALT activities) in streptozotocin-induced hyperglycemic ratsare presented in **Figure 2**. There was significant ($p \leq 0.05$) difference in AST, ALP and ALT activities in STZ alone when compared to the control. Treatment with *M. fulvum* significantly ($p \leq 0.05$) decreased AST, ALP and ALT activities in the treated group i.e. STZ + MF 1 and STZ + MF 2 groups when compared to the STZ alone group.

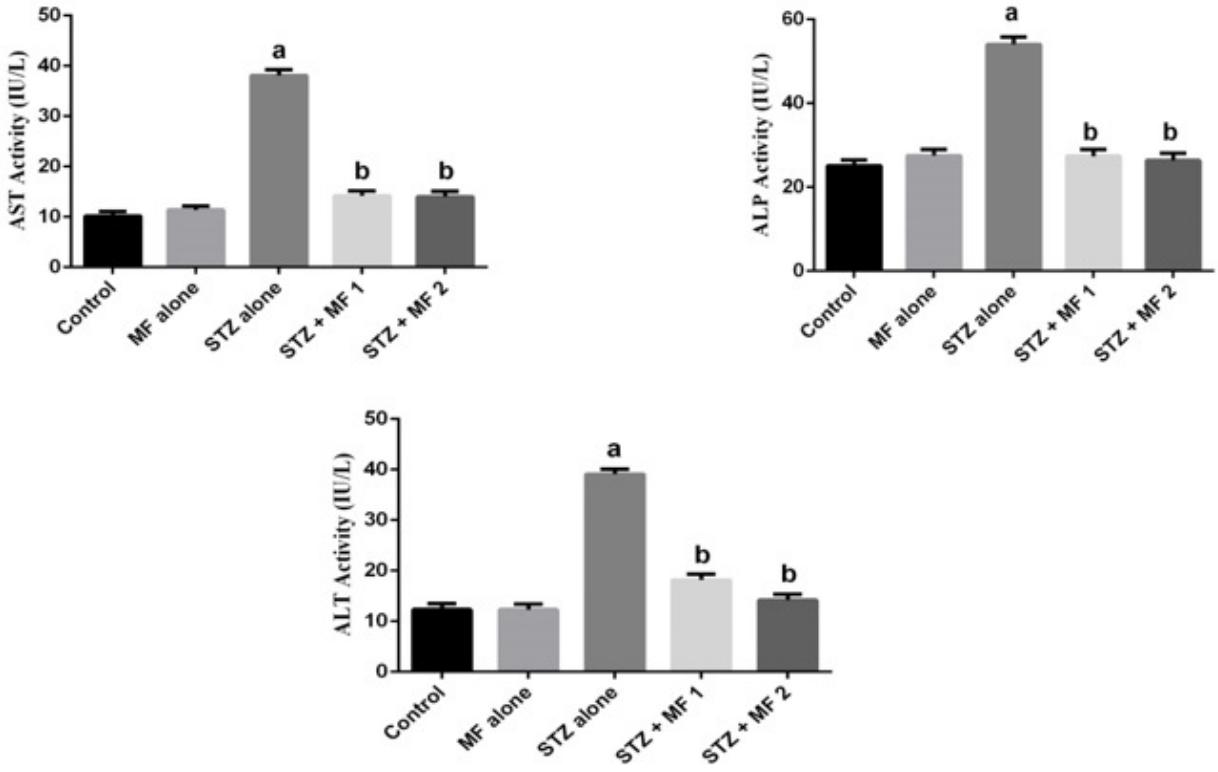

Figure 2: The effect of *M. fulvum* on streptozotocin – inducedhyperglycemicWistar rats on AST, ALT and ALP activity in serum of rat. streptozotocin, STZ; *M. fulvum,* MF; STZ (160 mg/kg body weight); MF 1, (83 mg/kg body weight); MF 2, (113 mg/kg body weight). The data are expressed as mean ± S.D. for 5 rats per group. a: Values differ significantly from control ($p \leq 0.05$). b: Values differ significantly from STZ alone at $p \leq 0.05$.

3.4. Effect of *M. fulvum* aqueous root extract on conjugated bilirubin, unconjugated bilirubin and total bilirubin levels of streptozotocin-induced hyperglycemicWistar rats

The effects of *M. fulvum* onconjugated bilirubin, unconjugated bilirubin and total bilirubin levels in streptozotocin-induced hyperglycemic ratsare presented in **Figure 3**. There was significant ($p \leq 0.05$) difference in conjugated bilirubin, unconjugated bilirubin and total bilirubin levels in STZ alone when compared to the control. Moreover, treatment with *M. fulvum*for 28 dayssignificantly ($p \leq 0.05$) decreased the levels of conjugated bilirubin, unconjugated bilirubin and total bilirubinin the treated group i.e. STZ + MF 1 and STZ + MF 2 groups when compared to the STZ alone group.

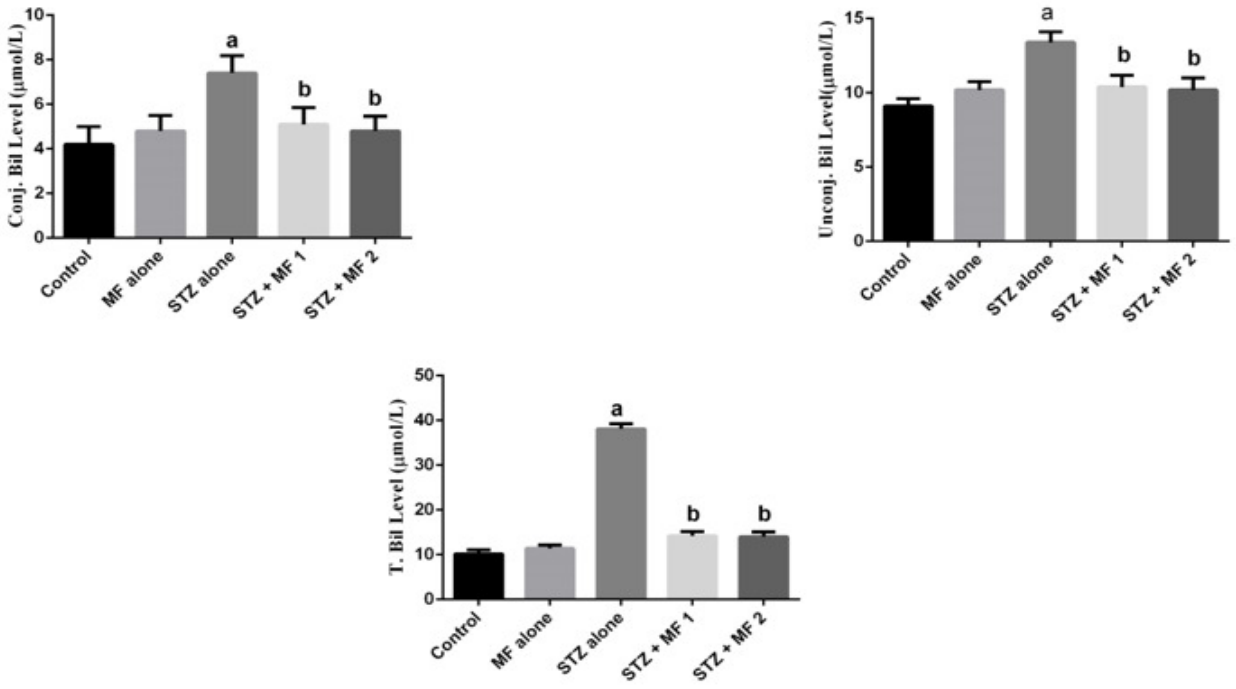

Figure 3: The effect of *M. fulvum* on streptozotocin – inducedhyperglycemicWistar rats on conjugated bilirubin, unconjugated bilirubin and total bilirubin levels in serum of rat. streptozotocin, STZ; *M. fulvum,* MF; STZ (160 mg/kg body weight); MF 1, (83 mg/kg body weight); MF 2, (113 mg/kg body weight). The data are expressed as mean ± S.D. for 5 rats per group. a: Values differ significantly from control ($p \leq 0.05$). b: Values differ significantly from STZ alone at $p \leq 0.05$.

3.5. Effect of *M. fulvum* aqueous root extract on cholesterol levels of streptozotocin-induced hyperglycemicWistar rats

The effects of *M. fulvum* on HDL – cholesterol, LDL – cholesterol, total cholesterol and triglyceride levels in streptozotocin-induced hyperglycemic ratsare presented in **Figure 4**. There was significant ($p \leq 0.05$) difference in HDL – cholesterol, LDL – cholesterol, total cholesterol and triglyceride levelsin STZ alone when compared to the control. But after treatment with *M. fulvum* for 28 days significantly ($p \leq 0.05$) decreased the levels of HDL – cholesterol, LDL – cholesterol, total cholesterol and triglyceride in the treated group i.e. STZ + MF 1 and STZ + MF 2 groups when compared to the STZ alone. Furthermore, there was also significant ($p \leq$

0.05) difference between STZ + MF 1 and STZ + MF 2 groups when compared to the control group.

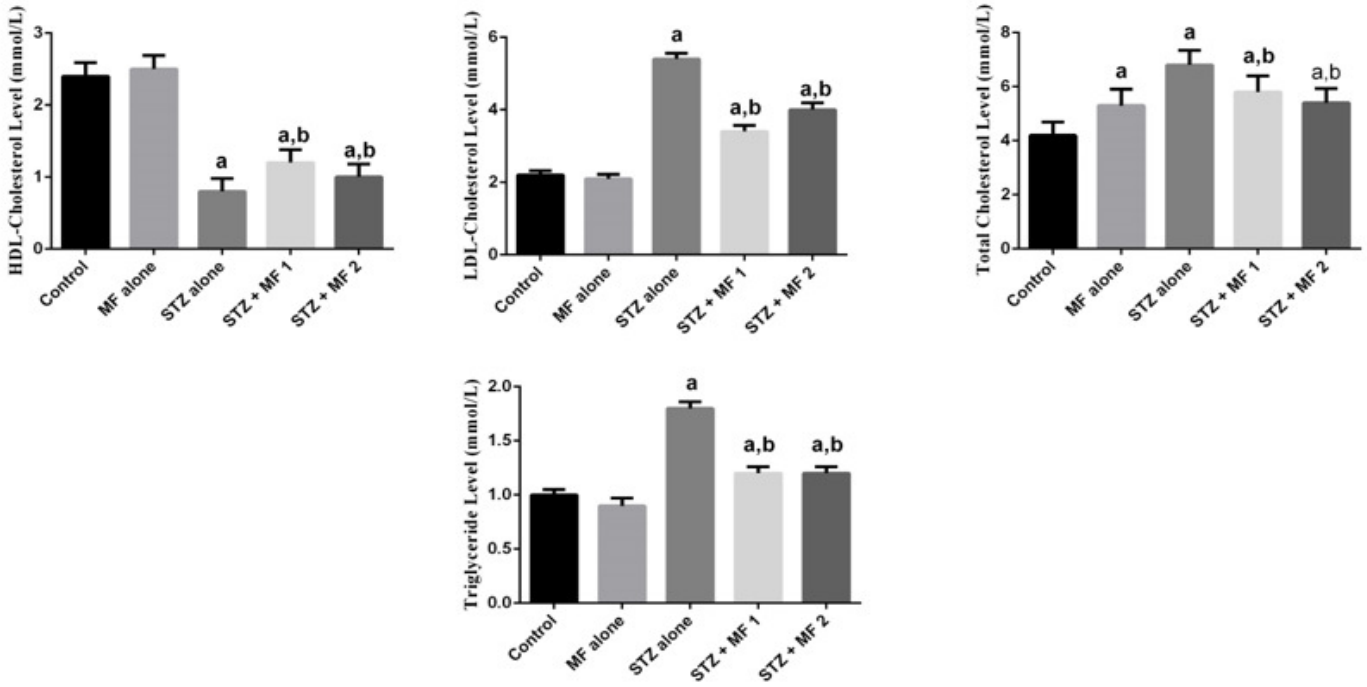

Figure 4: The effect of *M. fulvum* on streptozotocin – induced hyperglycemicWistar rats on HDL – C, LDL – C, total cholesterol and triglyceride levels in serum of rat. streptozotocin, STZ; *M. fulvum,* MF; STZ (160 mg/kg body weight); MF 1, (83 mg/kg body weight); MF 2, (113 mg/kg body weight). The data are expressed as mean ± S.D. for 5 rats per group. a: Values differ significantly from control ($p \leq 0.05$). b: Values differ significantly from STZ alone at $p \leq 0.05$.

3.6. Effect of *M. fulvum* aqueous root extract on urea andcreatinine levels of streptozotocin-induced diabetic Wistar rats

The effects of *M. fulvum* on urea and creatinine levels in streptozotocin-induced hyperglycemic ratsare presented in **Figure 5**. There was significant ($p \leq 0.05$) difference in urea and creatinine levelsin STZ alone when compared to the control. However, treatment with *M. fulvum* for 28

days significantly ($p \leq 0.05$) decreased the levels of urea and creatinine levelsin the treated group i.e. STZ + MF 1 and STZ + MF 2 groups when compared to the STZ alone.

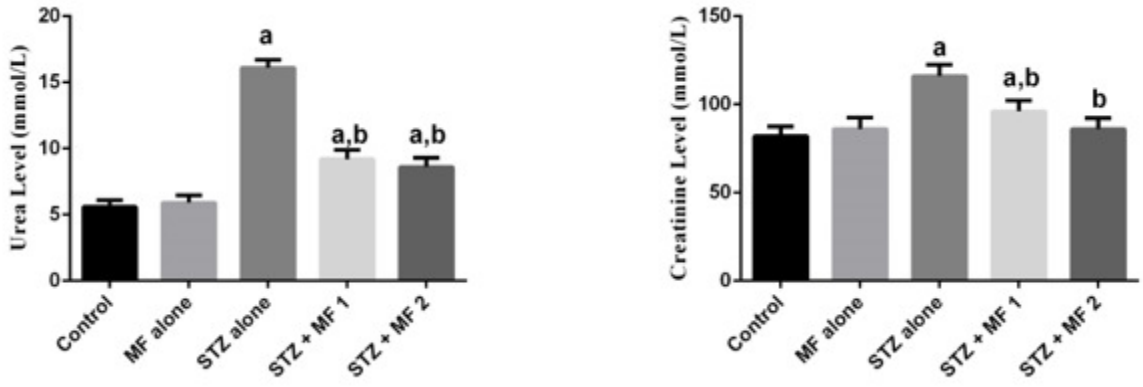

Figure 5: The effect of *M. fulvum* on streptozotocin – inducedhyperglycemicWistar rats on urea and creatinine levels in serum of rat. streptozotocin, STZ; *M. fulvum,* MF; STZ (160 mg/kg body weight); MF 1, (83 mg/kg body weight); MF 2, (113 mg/kg body weight). The data are expressed as mean ± S.D. for 5 rats per group. a: Values differ significantly from control ($p \leq 0.05$). b: Values differ significantly from STZ alone at $p \leq 0.05$.

3.7. Effect of *M. fulvum* aqueous root extract on cholesterol levels of streptozotocin-induced hyperglycemicWistar rats

The effects of *M. fulvum* on SOD and CAT activities as well as GSH and MDA levels in streptozotocin-induced hyperglycemic ratsare presented in **Figure 6**. There was significant ($p \leq 0.05$) difference in SOD and CAT activities as well as GSH and MDA levels in STZ alone when compared to the control. However, after 28 daystreatment with *M. fulvum*significantly ($p \leq 0.05$) increased SOD and CAT activities as well as GSH but significantly ($p \leq 0.05$) decreasedMDA levelsin the treated group i.e. STZ + MF 1 and STZ + MF 2 groups when compared to the STZ alone.

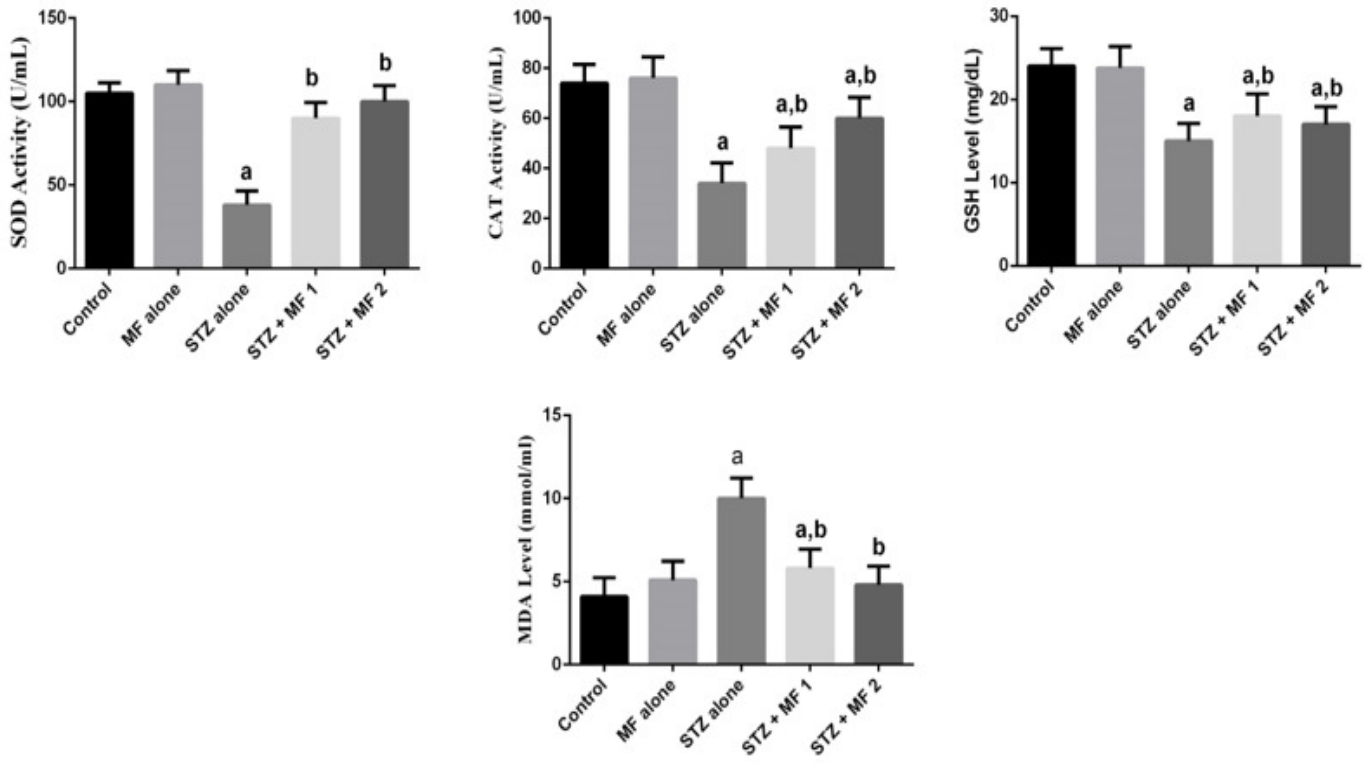

Figure 6: The effect of *M. fulvum* on streptozotocin – induced hyperglycemicWistar rats on SOD, CAT activities as well as GSH and M D A levels in serum of rat. streptozotocin, STZ; *M. fulvum,* MF; STZ (160 mg/kg body weight); MF 1, (83 mg/kg body weight); MF 2, (113 mg/kg body weight). The data are expressed as mean ± S.D. for 5 rats per group. a: Values differ significantly from control ($p \leq 0.05$). b: Values differ significantly from STZ alone at $p \leq 0.05$.

3.8. The Effect of *M. fulvum* on Streptozotocin – induced damages in the Pancreas

The Effect of *M. fulvum* on streptozotocin – induced damages in the pancreas is shown in **Figure 7.** Streptozotocin – inducedhyperglycemic rats had significant reduction in islet cell mass when compared to the control. However, after treatment with M. fulvum i.e. STZ + MF 1 an STZ + MF 2 groups significant increased the islet cell mass when compared with the STZ control group.

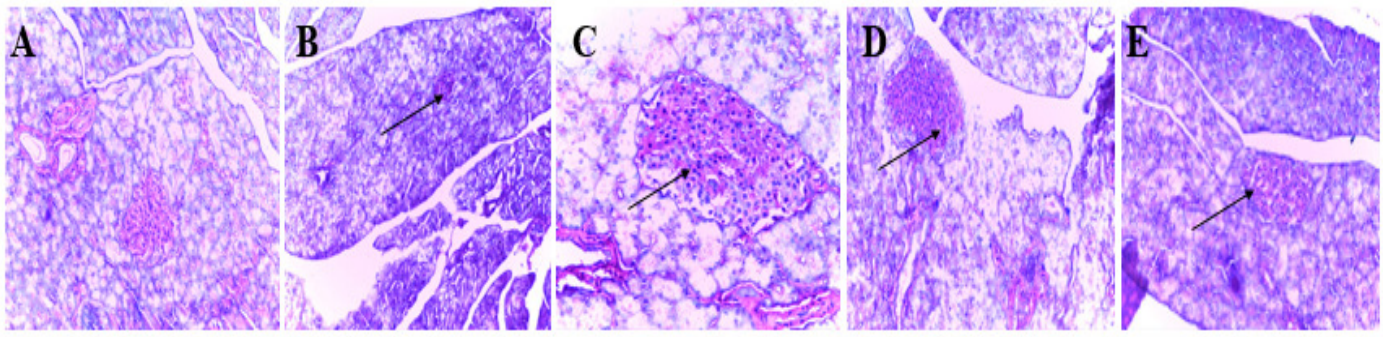

Figure 7: Representative histopathological sections of the pancreas from the experimental rats. The pancreas of rats from the control (**A**) and *M. fulvum* alone (**B**) groups showing normal morphology. The pancreas of rats administered with streptozotocin alone (**C**) showing marked pancreatic degeneration. However, the pancreas of rats co-administered with *M. fulvum* at 85 and 113 mg/kg, respectively (**D, E**) showing normal pancreas and it appeared structurally normal and similar to the control. Magnification of ×250.

Discussion

In the present study, we investigated the influence of *M. fulvum*against streptozotocin–inducedhyperglycemia and its complications in Wistar albino rats. Streptozotocin – induced hyperglycemia has been described by many scientist as a notable experimental model to diabetes mellitus (Junod et al., 1969; Bacanli et al., 2017). Streptozotocin is known tocauses massive reduction in insulin release as a result of the destruction of the β-cells of the islets of Langerhans, thereby resulting in the induction of hyperglycemia experimental model (Schein et al., 1973). Free radicals are generated disproportionately in diabetes experimental model (Bacanli et al., 2017). This may result in the simultaneous decline of antioxidant defense systems which may lead to damage of cellular organelles and enzymes, increased lipid peroxidation, and the subsequent development of insulin resistance. Al these complications may promote the development of complications of diabetes mellitus (Maritim et al., 2003).

Several local herbs are being used by the population as alternative therapy for the treatment of diabetes. Most of these herbs have not been subjected to scientific scrutiny to determine their potency. In the present study, we examine the antidiabetic influence of *M. fulvum* on streptozotocin – induced Wistar rats.Streptozotocin – induced significant increase in fasting blood glucose but *M. fulvum* lower the fasting bloo glucose level to normal in streptozotocin – induced Wistar rats.

The pancreas produces amylase which hydrolyses dietary starch into disaccharides and trisaccharides. High concentration of serum level of amylase indicates damage of pancreas. In the present study, streptozotocin – induced increased significant increase in amylase activity. This implies that streptozotocin may be the cause of the high pancreatic damage as also

suggested by previous researches (Kronke*et al.,* 1995; O'Brien *et al.,* 1996). However, *M fulvum* restored serum amylase activity to normal, indicating that *M. fulvum* ameliorate pancreatic damage induced by streptozotocin.

Liver function enzymes are important markers in diabetic diagnosis and management as it helps to determine the extent of liver damage. In the present study, there was significant increase in the liver function markers in the streptozotocin exposed group. However, *M. fulvum* significantly reduced the liver functions enzymes in the treated groups when compared with the control. The liver plays an important role in glycolysis andgluconeogenesis (Hiroshi et al., 1989), because it is an insulin dependent tissue, which plays a pivotal role in lipid homeostasis and glucose. In diabetic condition, the liver is severely affected (Gupta et al., 1999). In the present study, AST, ALT and ALP enzymes were significantly when compared to the control (Monami et al., 2008). It has been observed that AST, ALT an ALP enzymes activities in serum of 28 type 1 diabetic patients have elevated enzymes activities (Arkkila et al., 2001).The elevated conjugated and unconjugated bilirubin levels along with increased in total bilirubin observed in streptozotocin – induced rats may be an indication of hepatobiliary damages. However, *M. fulvum* was able to ameliorate the in increased in conjugated and unconjugated and total bilirubin.

M. fulvum treatment reduced serum triglycerides, low-density lipoprotein cholesterol(LDL-c) and fasting blood glucose levels and glucose tolerance, and increased serum high densitylipoprotein cholesterol (HDL-c), total cholesterol, and triglyceride. This lipid profile is used to measure hyperlipidaemia which is one of the complications of diabetes. In the present study, there was significant ($p < 0.05$) increase in HDL-C, LDL-C, total cholesterol, and triglyceridein the streptozotocin – induced group (**Figs. 4).** However, *M. fulvum* was observed to reduce the elevated levels of the serum lipid profile. The elevation of cholesterol in the diabetic

control group support the fact that in severe insulin deficiency, there is accelerated lipolysis which result in elevated plasma triacylglycerol level. In the diabetic state, as shown by the elevate fasting blood glucose level of same group. *M. fulvum* being a rich protein supplement and antioxidant, it might have antihyperlipidemic activities, thereby resulting in the reduction the rise in serum cholesterol.

Urea and creatinine are nitrogenous end product of metabolism. Urea is the primary metabolite derived from protein turnover while creatinine is the product of muscle catabolism. Elevation of urea and creatinine marks renal failure. Since renal failure is one of the complications of diabetes, the serum levels of urea and creatinine was investigated. Streptozotocin – induced rats show alterations in renal functional markers.There was significant ($p< 0.05$) increase in the renal functional markers (urea and creatinine) of the streptozotocin – induced group (**Figs. 5**). Similar alternation has been reported in several studies (Eidi et al. 2006; Erejuwa et al. 2011). However, *M. fulvum* was observed to reduce the elevated levels of renal functional markers, which has also been reported in several studies (Erejuwa et al. 2011; Devi et al. 2012).

The imbalance in pro-oxidants and antioxidants which can result in macromolecular damage (lipid peroxidation) and disruption of redox signalling leads to oxidative stress. The anti-oxidant enzymes (SOD, CAT and GSH) protect major macromolecules in cell from oxidative damage caused by reactive oxygen species (ROS). SOD catalyses the removal of superoxide radicals to generate hydrogen peroxide (H_2O_2) which in turn is decomposed by catalase (CAT) producing molecular oxygen and water which are not toxic. GSH plays a central role in detoxification and protection against the generation of free radicals thereby maintaining the integrity of cells. In the present study, the streptozotocin – induced oxidative stress (**Fig. 6**). However, *M. fulvum*significantly increased the plasma activities of superoxide dismutase and catalase, and

concentration of reduced glutathione, and reduced significantly the concentration of malondialdehyde. This antioxidant activity may be credited to quercetin present in the aqueous root extract of *M.fulvum*, hence, supporting the previous findings (Boots *et al.,* 2008; Bando *et al.,* 2010). Streptozotocin – induced rat's had significant histopathological damages found in the pancreas when compared with the control. However, *M. fulvum* treatmentwas able to minimize thepancreatic tissue damages.

Conclusion

The present study shows that *M. fulvum* possesses significant hypoglycemic, antihyperlipidemic and antioxidant effects in streptozotocin-induced hyperglycemic rats due to its ability to effectively reduced or ameliorate the increase in blood glucose levels, lipid profile and oxidative damages.

Conflict of Interest

The authors declare that there is no conflict of interest

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