

Effect of Methanol Leaf Extract of *Voacanga Africana* on Selected Biochemical Indices in Alloxan-Induced Diabetic Wistar Albino Rats

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Abstract—*Diabetes mellitus is a chronic metabolic disorder associated with persistent hyperglycaemia and progressive tissue disorder leading to organ damage. Medicinal plants remain a valuable source of alternative antidiabetic agents with potential efficacy and reduced side effects. Voacanga africana is traditionally used in the management of metabolic disorders; however, its antidiabetic potential has not been adequately validated scientifically. This study evaluated the effect of methanol leaf extract of Voacanga africana on blood glucose levels, body weight, glycated hemoglobin (HbA1c), and urinary albumin-creatinine ratio (UACR) in alloxan-induced diabetic Wistar albino rats. Diabetes was induced in rats using alloxan monohydrate. Animals were divided into eight groups comprising normal control, diabetic control, glibenclamide-treated, and extract-treated groups (200, 400, 600, 800, and 1000 mg/kg body weight). Treatments were administered orally for 21 days. Fasting blood glucose was monitored at regular intervals, body weight changes were recorded, while HbA1c and UACR were evaluated at the end of the experiment. Data were analyzed using one-way ANOVA. Alloxan-induced diabetic rats exhibited persistent hyperglycaemia, weight loss, elevated HbA1c, and increased UACR. Treatment with methanol leaf extract of Voacanga africana resulted in a significant ($p < 0.05$), dose-dependent reduction in fasting blood glucose levels and HbA1c, with higher doses showing effects comparable to glibenclamide. Extract-treated rats also demonstrated significant improvement in body weight and a marked reduction in UACR, indicating improved metabolic control and renal protection. Methanol leaf extract of Voacanga africana exhibits significant antidiabetic and renal protective effects in alloxan-induced diabetic rats. These findings support its traditional use and suggest its potential as a natural therapeutic agent for the management of diabetes mellitus and its associated complications.*

Keywords: *Voacanga Africana, Diabetes Mellitus, Alloxan, Blood Glucose, HbA1c, UACR, Medicinal Plants*

I. INTRODUCTION

Diabetes mellitus is a chronic metabolic disorder characterized by persistent hyperglycaemia resulting

from defects in insulin secretion, insulin action, or both. The global prevalence of diabetes continues to rise at an alarming rate, with developing countries bearing a disproportionate burden due to lifestyle changes, urbanization, and limited access to healthcare. Chronic hyperglycaemia in diabetes is associated with disturbances in carbohydrate, lipid, and protein metabolism, leading to long-term complications such as nephropathy, hepatopathy, cardiovascular diseases, and oxidative stress-mediated tissue damage (American Diabetes Association, 2023; IDF, 2021).

Experimental induction of diabetes using alloxan is a widely accepted model for studying antidiabetic agents. Alloxan selectively destroys pancreatic β -cells through the generation of reactive oxygen species, resulting in insulin deficiency and biochemical alterations that closely resemble type 1 diabetes mellitus in humans. This model is particularly useful for evaluating the effects of plant-derived compounds on biochemical indices such as blood glucose, lipid profile, liver enzymes, kidney function markers, and antioxidant parameters (Lenzen, 2008; Szkudelski, 2001).

Despite the availability of synthetic antidiabetic drugs, their long-term use is often associated with adverse effects, reduced efficacy, and high cost. Consequently, there is growing interest in medicinal plants as alternative or complementary therapies for diabetes management. Plants rich in bioactive phytochemicals such as alkaloids, flavonoids, saponins, and phenolic compounds have been shown to exert hypoglycaemic, antioxidant, and organ-protective effects in diabetic conditions (WHO, 2019; Sofowora et al., 2013).

Voacanga africana Stapf (family: Apocynaceae) is a tropical medicinal plant widely distributed in West and Central Africa and traditionally used for the

management of various ailments including diabetes, inflammation, hypertension, and mental disorders. Phytochemical studies have reported that *V. africana* leaves contain indole alkaloids, flavonoids, tannins, and other secondary metabolites known for their pharmacological activities, including antioxidant and glucose-lowering effects (Burkill, 2000; Neuwinger, 2000). However, scientific data validating its antidiabetic potential, particularly with respect to biochemical indices in experimental diabetes, remain limited.

Methanol is commonly employed as an extraction solvent due to its efficiency in extracting a wide range of polar and moderately non-polar phytochemicals. Methanolic leaf extracts of medicinal plants have demonstrated significant bioactivity in experimental models of metabolic disorders, suggesting their potential therapeutic relevance (Harborne, 1998; Tiwari et al., 2011).

Therefore, this study was designed to evaluate the effect of methanol leaf extract of *Voacanga africana* on selected biochemical indices in alloxan-induced diabetic Wistar albino rats. The findings from this study are expected to provide scientific evidence supporting the traditional use of *V. africana* and contribute to the search for safer, plant-based antidiabetic agents.

II. MATERIALS AND METHODS

Leaves of *V. africana* were collected from a local farm in Ukwu East Local Government Area of Abia State and were identified by the botanist, Dr. Duru C.M. of Department of Biological Sciences, Federal University of Technology Owerri, Imo State.

Preparation of Plant Material

The preparation of the leaves was done using the method as described by Agbafor (2004). The leaves of *V. africana* were washed in running tap water to remove adhering debris and were chopped into small sizes and dried for 14 days by air-drying under shade. The dried leaves were pulverized into coarse powder using a pulverizing machine.

Extraction of Plant Material

The extraction of the leaves was done using the method as described by Agbafor (2004). A 500 g of each of the ground plant samples was weighed and dispensed into 1500 ml of 95 % methanol. The

mixture was allowed to stand for 72 hours with intermittent shaking. Filtration of the samples were carried out using muslin cloth and then Whatman No. 3 filter paper and each of the filtrate was concentrated using rotary evaporator (at 40°C). The obtained semi-solid crude extract was stored in a refrigerator at 4°C for analysis.

Experimental Animals

Adult albino rats (120 -160 g) of either sex were purchased from Nano Farms Ihiagwa, Owerri, and was housed in the animal house of Department of Biochemistry, Federal Polytechnic Nekede, Owerri. All the animals were fed with a regular diet and water ad libitum. The rats were protected and cared for according to the principle of laboratory animal care. The rats were allowed to acclimatize for the period of 7 days under standard environmental conditions (temperature 25 ± 2 °C; 12hrs light/dark cycle).

Induction and Assessment of Diabetes

The method of Osinubi *et al.* (2006) and Battu *et al.* (2007) were employed. Diabetes was induced by injecting freshly prepared 120 mg/kg alloxan monohydrate intraperitoneally to overnight fasted albino rats. Hyperglycemia was confirmed three days after induction by drawing blood from the tail vein of the experimental animals. The animals showing Random Blood Glucose (RBG) level ≥ 250 mg/dl were selected for further study. The animals were maintained in a diabetic state for 21 days.

Experimental Design

Group 1 served as normal control and was given 10 ml/kg distilled water, group 2 served as treated diabetic control and was administered 2 mg/kg glibenclamide, group 3 served as untreated diabetic control, while group 4, 5, 6, 7 and 8 served as test groups and were administered 200, 400, 600, 800 and 1000 mg/kg b.w. of *Voacanga africana* respectively. The extracts and standard drug were administered orally and daily using gavage and administration lasted for 21 days.

Measurement of Body Weight

This was done following the method of Nagappa *et al.* (2003). Rats were individually weighed by means of a sensitive digital weighing balance (model B-218). Initial body weight before starting the experiment as well as at the end was recorded for all animals.

Measurement of Blood Glucose/ Anti-diabetic Evaluation

The method of Twari and Singh (2013) was used for the glucose measurement. Blood glucose concentration was measured on the initial 0 (baseline), 5th, 10th, 15th and 21st days of the study, to ascertain the hypoglycaemic effect of the extract on the rats being treated. This was done by slightly cutting the tail vein with a sharp scissors. Collection of blood samples was done by nipping and smearing the tail on the indicated portion of glucometer strip until it was fully soaked by blood after it was inserted into the Accu-check glucometer and blood glucose concentration was read within few seconds.

Collection of Blood Sample for Analysis

At the end of the experimental period, the animals were fasted overnight and sacrificed by cervical dislocation. The blood sample collection was through the ocular into a set of heparin bottles, then centrifuged at 2500rpm for 10 minutes to obtain the blood serum for analysis.

Determination of Glycated Hemoglobin (HbA1c)

Glycated hemoglobin (HbA1c) was determined using an immune turbid metric assay method described by Little and Sacks (2009).

0.5 mL of whole blood was collected from each rat via cardiac puncture into EDTA-coated tubes to prevent coagulation. Whole blood samples were gently mixed and 10 µL of each sample was transferred into a test tube containing 1.0 mL of hemolyzing reagent to lyse erythrocytes and release hemoglobin. The mixture was allowed to stand at room temperature for 5 minutes. Subsequently, 5 µL of the hemolysate was added to 500 µL of reagent R1 (buffer solution) and mixed thoroughly. Thereafter, 100 µL of reagent R2 containing anti-HbA1c antibodies was added. The reaction mixture was incubated at 37 °C for 5 minutes, during which antigen-antibody complexes formed, causing turbidity proportional to the HbA1c concentration. Absorbance was measured spectrophotometrically at a wavelength of 340 nm using a UV-Visible spectrophotometer. Total hemoglobin was determined separately using a cyanmethemoglobin method, and HbA1c was expressed as a percentage of total hemoglobin (% HbA1c) according to the formula below:

$$\text{HbA1c (\%)} = \left(\frac{\text{HbA1c concentration}}{\text{Total hemoglobin concentration}} \right) \times 100$$

Determination of Urinary Albumin-Creatinine Ratio (UACR)

Urinary albumin-creatinine ratio (UACR) was assessed according to method described by Mogensen (1999).

Rats were housed individually in metabolic cages for 24-hour urine collection. Urine samples were collected into sterile containers, centrifuged at 3000 rpm for 10 minutes to remove debris, and stored at -20 °C until analysis.

Determination of Urinary Albumin

Urinary albumin concentration was measured using a rat-specific ELISA method. Briefly, 50 µL of urine sample or standard was added into each well of a microplate pre-coated with anti-rat albumin antibodies. This was followed by the addition of 50 µL of enzyme-linked secondary antibody. The plate was incubated at 37 °C for 30 minutes and then washed five times with wash buffer to remove unbound material. Subsequently, 100 µL of chromogenic substrate solution (TMB) was added to each well and incubated in the dark for 10 minutes. The reaction was stopped by adding 50 µL of stop solution (2 M sulfuric acid). Absorbance was read at a wavelength of 450 nm using a microplate reader, and albumin concentration was calculated from a standard curve.

Determination of Urinary Creatinine

Urinary creatinine concentration was determined using the Jaffé kinetic method. In brief, 100 µL of urine sample was mixed with 1.0 mL of alkaline picrate reagent. The reaction mixture was incubated at room temperature, and absorbance was measured at 520 nm at 30 seconds and 120 seconds intervals. Creatinine concentration was calculated using a standard calibration curve. The urinary albumin-creatinine ratio was calculated using the formula:

$$\text{UACR (mg/g)} = \left(\frac{\text{Urinary albumin (mg/dL)}}{\text{Urinary creatinine (g/gL)}} \right)$$

Statistical Analysis

Data generated from the study was presented as mean ± SEM. Statistical analysis was done by One-way analysis of variance using the SPSS version 21.0. The mean difference at P<0.05 was considered statistically significant.

III. RESULTS AND DISCUSSION

Table 1: Results of Effect of Methanol Leaf Extract of *Voacanga africana* on Fasting Blood Glucose Levels in Alloxan-Induced Diabetic Rats.

Group	Fasting Blood Glucose Levels (mg/dL)				
	Day 0	Day 5	Day 10	Day 15	Day 21
Normal control	91.4 ± 3.1 ^a	92.0 ± 2.8 ^a	92.6 ± 3.0 ^a	94.2 ± 2.6 ^a	93.1 ± 2.9 ^a
Diabetic + Glibenclamide	314.6 ± 8.4 ^b	241.3 ± 7.1 ^c	183.5 ± 6.2 ^d	129.7 ± 5.4 ^e	109.3 ± 4.6 ^{ac}
Diabetic control	318.2 ± 9.1 ^b	325.6 ± 10.3 ^b	332.8 ± 9.7 ^b	340.1 ± 11.2 ^b	336.5 ± 12.0 ^b
<i>V.africana</i> 200 mg/kg	310.4 ± 8.9 ^b	280.6 ± 7.8 ^c	245.4 ± 7.2 ^c	210.3 ± 6.9 ^c	185.6 ± 6.4 ^c
<i>V.africana</i> 400 mg/kg	318.9 ± 9.3 ^b	275.1 ± 8.2 ^c	220.6 ± 6.8 ^d	180.2 ± 6.1 ^d	135.7 ± 5.8 ^d
<i>V.africana</i> 600 mg/kg	331.6 ± 8.7 ^b	240.4 ± 7.5 ^c	180.3 ± 6.4 ^d	140.5 ± 5.9 ^e	119.6 ± 4.9 ^e
<i>V.africana</i> 800 mg/kg	320.3 ± 9.0 ^b	215.6 ± 6.9 ^d	165.8 ± 5.8 ^e	130.6 ± 4.7 ^e	109.4 ± 4.3 ^{ac}
<i>V.africana</i> 1000 mg/kg	319.1 ± 8.5 ^b	204.4 ± 6.4 ^d	155.7 ± 5.6 ^e	120.3 ± 4.5 ^e	101.8 ± 4.1 ^a

Values are mean ± SEM (n = 6). Values with different superscript letters within the same column differ significantly (p < 0.05).

Table 2: Results of Effect of Methanol Leaf Extract of *Voacanga africana* on Body Weight Changes.

Group	Body Weight Changes (g)	
	Initial weight	Final weight
Normal control	172.5 ± 4.3 ^a	200.6 ± 5.1 ^a
Diabetic + Glibenclamide	170.7 ± 4.6 ^a	290.8 ± 4.9 ^{ab}
Diabetic control	171.2 ± 4.5 ^a	146.4 ± 4.2 ^c
<i>V.africana</i> 200 mg/kg	173.1 ± 4.8 ^a	158.7 ± 4.4 ^c
<i>V.africana</i> 400 mg/kg	172.4 ± 4.6 ^a	168.5 ± 4.7 ^{bc}
<i>V.africana</i> 600 mg/kg	171.9 ± 4.9 ^a	177.6 ± 4.8 ^b
<i>V.africana</i> 800 mg/kg	172.8 ± 4.5 ^a	188.2 ± 5.0 ^{ab}
<i>V.africana</i> 1000 mg/kg	173.6 ± 4.7 ^a	194.1 ± 5.2 ^a

Values are mean ± SEM (n = 6). Values with different superscript letters within the same column differ significantly (p < 0.05).

Table 3: Results of Effect of Methanol Leaf Extract of *Voacanga africana* on Glycated Hemoglobin (HbA1c) and Urinary Albumin–Creatinine Ratio (UACR)

Group	HbA1c (%)	UACR (mg/g)
Normal control	4.5 ± 0.2 ^a	22.5 ± 1.6 ^a
Diabetic + Glibenclamide	5.1 ± 0.3 ^{ab}	28.5 ± 1.9 ^{ab}
Diabetic control	9.7 ± 0.4 ^c	96.7 ± 4.3 ^c
<i>V.africana</i> 200 mg/kg	8.5 ± 0.3 ^c	78.3 ± 3.7 ^c
<i>V.africana</i> 400 mg/kg	7.3 ± 0.3 ^d	60.4 ± 3.2 ^d
<i>V.africana</i> 600 mg/kg	6.2 ± 0.2 ^b	45.5 ± 2.8 ^c
<i>V.africana</i> 800 mg/kg	5.5 ± 0.2 ^{ab}	32.6 ± 2.1 ^{ab}
<i>V.africana</i> 1000 mg/kg	5.0 ± 0.2 ^a	26.3 ± 1.9 ^a

Values are mean ± SEM (n = 6). Values with different superscript letters within the same column differ significantly (p < 0.05).

IV. DISCUSSION

The present study evaluated the antidiabetic potential of methanol leaf extract of *Voacanga africana* by assessing its effects on fasting blood glucose, body weight, glycated hemoglobin (HbA1c), and urinary albumin–creatinine ratio (UACR) in alloxan-induced diabetic Wistar albino rats. The persistent hyperglycaemia observed in untreated diabetic rats confirms the diabetogenic action of alloxan, which selectively destroys pancreatic β-cells via oxidative stress mechanisms, leading to insulin deficiency and metabolic dysregulation (Szkudelski, 2001; Lenzen, 2008).

Treatment with methanol leaf extract of *Voacanga africana* resulted in a dose-dependent and progressive reduction in blood glucose levels over the 21-day treatment period. Rats treated with 200 and 400 mg/kg showed moderate reductions, whereas those administered 600, 800, and 1000 mg/kg exhibited marked decreases in glucose levels. Notably, the hypoglycaemic effect observed at 800 and 1000 mg/kg was comparable to that of the

standard antidiabetic drug, glibenclamide, by day 21 of treatment (p > 0.05). The normal control group maintained stable normoglycaemic values throughout the study. The significant reduction in fasting blood glucose levels in extract-treated groups indicates a potent hypoglycaemic effect of *V. africana*. The dose-dependent response observed suggests a direct pharmacological action of the extract, possibly through enhanced insulin secretion, improved insulin sensitivity, or increased peripheral glucose uptake. The comparable glucose-lowering effect of higher extract doses with glibenclamide further supports its antidiabetic potential. Similar findings have been reported for medicinal plants rich in alkaloids and flavonoids, which are known to exert insulinotropic and insulin-mimetic effects (Modak et al., 2007; Tiwari et al., 2011).

Body weight loss is a common clinical and experimental manifestation of uncontrolled diabetes and is largely associated with enhanced muscle wasting and protein catabolism due to insulin deficiency (Grover et al., 2000). Changes in body weight are presented in Figure 2. Diabetic control rats

showed a significant ($p < 0.05$) reduction in body weight at the end of the experimental period compared with their initial weights and the normal control group. In contrast, treatment with methanol leaf extract of *Voacanga africana* resulted in a dose-dependent improvement in body weight. Rats treated with higher doses (600–1000 mg/kg) demonstrated significant weight gain compared with the diabetic control group, with the 800 and 1000 mg/kg groups showing body weight values comparable to the glibenclamide-treated group. The normal control group exhibited normal physiological weight gain over the 21-day period.

Diabetes-induced body weight loss observed in untreated rats is consistent with enhanced proteolysis, lipolysis, and muscle wasting resulting from insulin deficiency. The improvement in body weight seen in extract-treated groups further supports the restoration of metabolic balance and improved glucose utilization. These effects may be attributed to improved insulin action and reduced oxidative stress, which are essential for maintaining normal anabolic processes (Grover et al., 2000).

HbA1c is a critical biomarker reflecting long-term glycaemic control, as it represents the non-enzymatic glycation of hemoglobin over the lifespan of red blood cells. The significantly elevated HbA1c levels observed in diabetic control rats in this study indicate prolonged hyperglycaemia and poor glycaemic control. Treatment with methanol leaf extract of *Voacanga africana* resulted in a significant, dose-dependent reduction in HbA1c levels, with higher doses producing values comparable to the standard drug. This finding suggests sustained improvement in blood glucose regulation over the treatment period, rather than a transient hypoglycaemic effect. Similar reductions in HbA1c have been documented following treatment with plant extracts possessing antioxidant and insulin-enhancing properties (American Diabetes Association, 2023; Eidi et al., 2006).

UACR is a sensitive indicator of renal dysfunction and an early marker of diabetic nephropathy. The significantly elevated UACR observed in diabetic control rats in this study reflects increased glomerular permeability and renal damage resulting from chronic hyperglycaemia. Treatment with methanol leaf extract of *V. africana* significantly reduced UACR levels in a dose-dependent manner,

suggesting a protective effect on renal function. The reduction in albuminuria may be attributed to improved glycaemic control and antioxidant-mediated stabilization of the glomerular filtration barrier. Previous studies have demonstrated that plant-derived antioxidants can attenuate diabetes-induced renal damage by reducing oxidative stress and inflammation (Forbes & Cooper, 2013; Ha & Kim, 1999).

The combined improvement in fasting blood glucose, HbA1c, body weight, and UACR observed in this study indicates that methanol leaf extract of *Voacanga africana* exerts both glycaemic control and organ-protective effects in experimental diabetes. These effects are likely mediated by the plant's phytochemical constituents, particularly indole alkaloids and phenolic compounds, which have been reported to possess antioxidant, anti-inflammatory, and insulin-modulating activities (Sofowora et al., 2013; Neuwinger, 2000).

Overall, the findings provide strong experimental evidence supporting the traditional use of *Voacanga africana* in the management of diabetes mellitus and its associated complications. The extract's ability to improve long-term glycaemic control and mitigate renal dysfunction highlights its potential as a complementary therapeutic agent in diabetes management.

V. CONCLUSION

The findings of this study demonstrate that methanol leaf extract of *Voacanga africana* possesses significant antidiabetic activity in alloxan-induced diabetic Wistar albino rats. The extract effectively reduced fasting blood glucose levels and glycated hemoglobin, indicating both short-term and long-term improvement in glycaemic control. Additionally, the dose-dependent improvement in body weight suggests restoration of normal metabolic function, while the marked reduction in urinary albumin–creatinine ratio highlights a protective effect against diabetes-induced renal damage.

REFERENCES

- [1]. Agbafor, K.N. (2004). The Effects of Aqueous and Organic Extract of *Baphian nitida* on tissue acetylcholine Esterase in Guinea Pigs. *Journal of Science and Technology*, 10(7);1-6

- [2]. American Diabetes Association (2023). Classification and diagnosis of diabetes. *Diabetes Care*, 46(Suppl. 1), S19–S40.
- [3]. Battu, G.R., Mamidipalli, S.N., Parimi, R., Viriyala, R.K., Patchula, R.P. and Mood L.R. (2007). Hypoglycaemic and antihyperglycemic effect of alcoholic extract of *Benincasa hispida* in normal and in alloxan induced diabetic rats. *Pharmacognosy Magazine*.
- [4]. Burkill, H. M. (2000). *The useful plants of West Tropical Africa* (Vol. 5). Royal Botanic Gardens, Kew.
- [5]. Eidi, A., Eidi, M., & Esmacili, E. (2006). Antidiabetic effect of *Salvia officinalis* L. in normal and diabetic rats. *Phytotherapy Research*, 20, 882–887.
- [6]. Forbes, J. M., & Cooper, M. E. (2013). Mechanisms of diabetic complications. *Physiological Reviews*, 93, 137–188.
- [7]. Grover, J. K., Vats, V., & Rathi, S. S. (2000). Anti-hyperglycemic effect of medicinal plants in experimental diabetes. *Journal of Ethnopharmacology*, 73, 461–470.
- [8]. Ha, H., & Kim, K. H. (1999). Role of oxidative stress in the development of diabetic nephropathy. *Kidney International*, 56, S18–S21.
- [9]. Harborne, J. B. (1998). *Phytochemical methods: A guide to modern techniques of plant analysis*. Chapman & Hall.
- [10]. International Diabetes Federation (IDF) (2021). *IDF Diabetes Atlas* (10th ed.). Brussels, Belgium.
- [11]. Lenzen, S. (2008). The mechanisms of alloxan- and streptozotocin-induced diabetes. *Diabetologia*, 51, 216–226.
- [12]. Lenzen, S. (2008). The mechanisms of alloxan- and streptozotocin-induced diabetes. *Diabetologia*, 51, 216–226.
- [13]. Little, R. R., & Sacks, D. B. (2009). HbA1c: How do we measure it and what does it mean? *Current Opinion in Endocrinology, Diabetes and Obesity*, 16(2), 113–118.
- [14]. Modak, M., Dixit, P., Londhe, J., Ghaskadbi, S., & Devasagayam, T. P. A. (2007). Indian herbs and herbal drugs used for the treatment of diabetes. *Journal of Clinical Biochemistry and Nutrition*, 40, 163–173.
- [15]. Mogensen, C. E. (1999). Microalbuminuria and hypertension in diabetes. *Journal of Internal Medicine*, 245(5), 381–391.
- [16]. Nagappa, A.N., Thakurdesai, P.A., Venkat, R. N. and Singh, J. (2003). Antidiabetic activity of *Terminalia catappa* linn fruits. *Journal of Ethanopharmacology*. 88:45-50.
- [17]. Neuwinger, H. D. (2000). *African traditional medicine: A dictionary of plant use and applications*. Medpharm Scientific Publishers.
- [18]. Neuwinger, H. D. (2000). *African traditional medicine: A dictionary of plant use and applications*. Medpharm Scientific Publishers.
- [19]. Osinubi, A.A., Ajayi, O.G., Adesiyun, A.E. (2006). Evaluation of the anti-diabetic effect of aqueous leaf extracts of *Tripinanthus butungil* in male spragne Dawley rats. 101 – 105.
- [20]. Sofowora, A., Ogunbodede, E., & Onayade, A. (2013). The role and place of medicinal plants in disease prevention. *African Journal of Traditional, Complementary and Alternative Medicines*, 10(5), 210–229.
- [21]. Sofowora, A., Ogunbodede, E., & Onayade, A. (2013). The role and place of medicinal plants in the strategies for disease prevention. *African Journal of Traditional, Complementary and Alternative Medicines*, 10(5), 210–229.
- [22]. Szkudelski, T. (2001). The mechanism of alloxan and streptozotocin action in β -cells of the rat pancreas. *Physiological Research*, 50, 537–546.
- [23]. Szkudelski, T. (2001). The mechanism of alloxan and streptozotocin action in β -cells of the rat pancreas. *Physiological Research*, 50, 537–546.
- [24]. Tiwari, P., Kumar, B., Kaur, M., Kaur, G., & Kaur, H. (2011). Phytochemical screening and extraction: A review. *Internationale Pharmaceutica Scientia*, 1(1), 98–106.
- [25]. Tiwari, P., Kumar, B., Kaur, M., Kaur, G., & Kaur, H. (2011). Phytochemical screening and extraction: A review. *Internationale Pharmaceutica Scientia*, 1(1), 98–106.
- [26]. Tiwari, V. and Singh, A. (2013). Antinociceptive and antioxidant potential of *Bauhinia tomentosa* extracts in experimental animal models. *National Productivity Journal*. 3:309–316.
- [27]. World Health Organization (2019). *WHO global report on diabetes*. Geneva.