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Ethanol Extract of *C. Sativus* Modulates the Activity of Glucose 6-Phosphatase/ Aminotransferases and Levels of Lipids in Tissues of STZ-Induced Diabetic Rats

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ABSTRACT

The present study investigated the potential of ethanol extract of Cucumis sativus fruit in the modulation of the activity of glucose 6-phosphatase (G6Pase)/aminotransferases and levels of lipids in tissues of streptozotocin (STZ)-induced diabetic rats. Male albino rats of Wistar strain (n = 25, mean weight = 215 ± 15 g) were assigned to five groups (5 rats/group): normal control, diabetic, metformin, extract (200 mg/kg body weight, bwt) and extract (300 mg/kg bwt) groups. A single intraperitoneal injection of 50 mg/kg bwt STZ was used to induce diabetes mellitus (DM) in the experimental rats. The diabetic rats were then treated for 21 days with 50 mg/kg bwt metformin (standard antidiabetic agent) or the extract. Activities of G6Pase, alanine aminotransferase (ALT), aspartate aminotransferase (AST) and alkaline phosphatase (ALP) and levels of total cholesterol (TC), triacylglycerol (TG), very low-density lipoprotein cholesterol (VLDL-C), and nitric oxide (NO) were measured in plasma or tissues (liver/heart/kidney). The results showed that STZ-induced DM significantly increased G6Pase activity in the plasma as well as liver and kidneys of rats ($p < 0.05$). However, the activity of the enzyme was markedly reduced after treatment with ethanol extract of *C. sativus* fruit. The diabetogenic agent STZ markedly elevated the activities of ALT and ALP in rat hepatic tissue ($p < 0.05$), but it did not alter the activity of AST in hepatic and cardiac tissues ($p > 0.05$). On the contrary, treatment of the diabetic rats with the medicinal plant extract significantly reduced the hepatic activities of ALT and ALP ($p < 0.05$). Similarly, induction of DM with STZ led to significant increase in the level of hepatic lipids (TC, TG and VLDL-C) and plasma NO, while treatment of the diabetic Wistar rats significantly reversed the effect of STZ by markedly reducing hepatic lipids and plasma NO levels ($p < 0.05$). These results indicate that ethanol extract of *C. sativus* fruit has the potential to modulate the activity of G6Pase/aminotransferases and levels of lipids in tissues of STZ-induced diabetic rats.

Keywords: Aminotransferases; Diabetes Mellitus; Lipids; Medicinal Plant; Nitric Oxide

Abbreviations: G6Pase: Glucose 6-Phosphatase; STZ: Streptozotocin; ALT: Alanine Aminotransferase; AST: Aspartate Aminotransferase; ALP: Alkaline Phosphatase; TC: Total Cholesterol; TG: Triacylglycerol; VLDL-C: Very Low-Density Lipoprotein Cholesterol; NO: Nitric Oxide; DM: Diabetes Mellitus; FBG: Fasting Blood Glucose; BDH: British Drug House

Introduction

Diabetes mellitus (DM) is a heterogeneous group of syndromes characterized by an elevation of fasting blood glucose (FBG) caused by a relative or absolute deficiency in insulin [1]. It is one of the oldest diseases of man, and the most common metabolic disorder that affects millions of people all over the world [2]. Diabetes mellitus is a major cause of heart disease, high blood pressure and stroke. Death rates for heart disease and the risk of stroke are about 2 – 4 times higher among adults with DM than among those without the disease [3]. For individuals with DM, high blood pressure, high blood cholesterol, and smoking increase the risk of heart disease and stroke [4]. Mean medical expenses are more than twice as high for diabetic indi-

viduals as they are for non-diabetic individuals [1]. The most common forms of DM are: type 1 DM (T1DM), type 2 DM (T2DM), gestational diabetes and maturity-onset diabetes of the youth (MODY) [5]. Type 1 DM (TIDM) is characterized by an absolute deficiency of insulin caused by autoimmune attack on cells of the pancreas. In TIDM, the islets of Langerhans become infiltrated with activated T-lymphocytes leading to insulitis. Over a period of years, this autoimmune attack leads to gradual depletion of β-cell population. However, symptoms appear abruptly when 80 – 90 % of β-cells have been destroyed. At this point, the pancreas fails to respond adequately to ingestion of glucose, and insulin therapy is required to restore metabolic control and prevent life-threatening ketoacidosis. This β-cell destruction requires both a stimulus from the environment (such as viral infection) and a genetic determinant that allows β-cells to be recognized as "non-self" [1,6-8]. Type-2 DM (T2DM), the most common form of DM, develops gradually without obvious symptoms. The disease is often detected using routine screening tests. However, many individuals with T2DM have symptoms of polyuria (excessive urination) and polydipsia (excess thirst) of several weeks duration. The metabolic alterations observed in T2DM are milder than those described for the insulin-dependent form of the disease, in part, because insulin secretion in T2DM although not adequate does not restrain ketogenesis and block the development of diabetic ketoacidosis. Diagnosis is based most commonly on the presence of hyperglycemia [1,2]. The disease does not involve viruses or autoimmune antibodies [9]. The metabolic abnormalities of T2DM are the result of insulin resistance expressed primarily in liver, muscle, and adipose tissue. These are: hyperglycemia and hypertriacylglycerolemia [9]. Among the metabolic pathways affected in DM is gluconeogenesis, with the principal/regulatory enzyme being G6Pase.

People in developing and poor countries rely heavily on medicinal plants for certain aspects of their health [10-14]. These plants are speculated to be effective in treating illnesses/diseases [15-17]. Cucumis sativus is a medicinal plant with varied biological/pharmacological activities. This study investigated the potential of ethanol extract of *C. sativus* fruit in the modulation of the activity of G6Pase/aminotransferases and levels of lipids in tissues of STZ-induced diabetic rats.

Materials and Methods

Drugs and Chemicals

The standard antidiabetic drug, metformin, was purchased from Micronova Laboratories (India), and STZ was a product of British Drug House (BDH) Chemicals Ltd. (England). Absolute ethanol, chloroform, and other materials/glass wares were obtained from Bell, Sons & Co. (England), while formaldehyde was purchased from Thermo Fisher Scientific Ltd. (USA). Glucose 6-phosphatase assay kit was obtained from Abcam (UK). All the chemicals and solvents used in this study were of analytical grade.

Plant Preparation and Extraction

Freshly harvested Cucumis sativus fruits were purchased from a major fruit/vegetable market in Benin City, Nigeria and identified by a Botanist at Plant Biology and Biotechnology Depart-ment, University of Benin. They were thereafter washed and air-dried for 4 weeks at the Department of Biochemistry. The dry plant material was pulverized with a mechanical blender. The ground sample was cold macerated in absolute ethanol for three days (72 h) in a bell jar and filtered using Whatmann filter paper No. 42 (125 mm). The ethanol extract was thereafter concentrated using rotary evaporator and freeze-dried via lyophilization [18,19].

Experimental Rats

Mature male albino rats (Wistar strain, n = 25) weighing 200 to 230 g (mean weight = 215 ± 15 g) were purchased from the Department of Anatomy, University of Benin, Nigeria and housed in wooden cages. They were acclimatized for two weeks before commencement of the study and had free access to feed and clean water.

Experimental Design

The rats were randomly assigned to five groups (5 rats/group): normal control, diabetic, metformin, 200 mg/kg bwt extract and 300 mg/kg bwt extract groups. Diabetes mellitus was induced in the rats using STZ (single intraperitoneal injection of 50 mg/kg bwt). The diabetic rats were then treated with standard antidiabetic drug, metformin (50 mg/kg bwt) or the extract (200 and 300 mg/ kg bwt, respectively), for 21 days.

Collection of Blood

At the end of the treatment period, the rats were subjected to mild chloroform anesthesia after an overnight fast. They were euthanized and blood was collected via retro-orbital sinus puncture and centrifuged for 10 min at 3000 rpm to obtain plasma. Organs such as liver, kidney and heart were excised, blotted dry and used to prepare 20 % tissue homogenate.

Biochemical Analyses

Activities of AST, ALT and ALP as well as levels of TP, TC, TG and VLDL-C were measured in tissue homogenate [20-25]. Glucose 6-phosphatase activity was determined in plasma, liver and kidney, while NO level was estimated in plasma only [26, 27].

Statistical Analysis

Data are presented as mean ± standard error of mean (SEM, n = 5). Statistical analysis was performed using SPSS version 21. Statistical differences between means were compared using Duncan multiple range test. Statistical significance was assumed at $p < 0.05$

Results

Effect of Ethanol Extract of *C. Sativus* on G6Pase Activity

Streptozotocin-induced DM significantly increased G6Pase activity in the plasma as well as liver and kidneys of rats ($p < 0.05$). However, the activity of the enzyme was markedly reduced after treatment with ethanol extract of *C. sativus* fruit ($p < 0.05$; Table 1).

Table 1: Activity of G6Pase in the Different Groups.

Group		G6Pase (U/min) x10^{-3}	
	Plasma	Liver	Kidney
Normal Control	2.19 ± 0.01	2.32 ± 0.13	1.72 ± 0.20
Diabetic	12.38 ± 0.81[a]	9.75 ± 0.75[a]	6.44 ± 0.70[a]
Metformin	5.01 ± 0.60[b]	2.16 ± 0.48[b]	2.19 ± 0.30[b]
Extract (200 mg/kg bwt)	3.81 ± 0.54[b]	1.94 ± 0.10[b]	2.13 ± 0.20[b]
Extract (300 mg/kg bwt)	5.54 ± 0.56[b]	2.07 ± 0.51[b]	2.16 ± 0.30[b]

Note: Data are plasma and tissue activities of G6Pase and are expressed as mean ± SEM (n = 5).
[a]$p < 0.05$, when compared with normal control group

[b]$p < 0.05$, when compared with diabetic group

Effect of Ethanol Extract of *C. Sativus* on Tissue Activity of AST, ALT and ALP

Streptozotocin markedly elevated the activities of ALT and ALP in rat hepatic tissue ($p < 0.05$), but it did not alter the activity of AST in hepatic and cardiac tissues ($p > 0.05$). On the contrary, treatment of the diabetic rats with the medicinal plant extract significantly reduced the hepatic activities of ALT and ALP ($p < 0.05$). These results are shown in Table 2.

Table 2: Tissue Activity of AST and ALT.

Group	AST (U/L)		ALT (U/L)	ALP (U/L)
	Heart	Liver	Liver	Liver
Normal Control	130.00 ± 1.08	151.23 ± 6.49	37.54 ± 4.01	37.97 ± 4.18
Diabetic	130.00 ± 6.32	152.11 ± 1.06	53.02 ± 2.85[a]	193.50 ± 7.32[a]
Metformin	130.53 ± 4.21	148.95 ± 3.11	35.11 ± 1.00[b]	165.44 ± 9.11[b]
Extract (200 mg/kg bwt)	133.66 ± 3.67	157.18 ± 1.90	36.03 ± 3.02[b]	157.11 ± 16.07[b]
Extract (300 mg/kg bwt)	135.79 ± 3.42	146.84 ± 2.62	41.27 ± 3.07[b]	105.77 ± 13.56[b]

Note: Data are tissue AST, ALT and ALP activity, and are expressed as mean ± SEM (n = 5).
[a]$p < 0.05$, when compared with normal control group

[b]$p < 0.05$, when compared with diabetic group

Effect of Ethanol Extract of *C. Sativus* on Tissue Lipids and NO Level

Induction of DM with STZ led to significant increase in the level of hepatic lipids (TC, TG and VLDL-C) and plasma NO, while treatment of the diabetic Wistar rats significantly reversed the effect of STZ by markedly reducing hepatic lipids and plasma NO levels ($p < 0.05$; Tables 3 & 4).

Table 3: Levels of Tissue Lipids and Plasma TP.

Group	TP (g/dL)	TC (mg/dL)	TG (mg/dL)	VLDL-C (mg/dL)
	Plasma	Liver	Liver	Liver
Normal Control	6.03 ± 0.30	25.10 ± 1.20	31.52 ± 5.54	6.30 ± 0.52
Diabetic	16.71 ± 2.84[a]	43.42 ± 4.00[a]	75.07 ± 7.22[a]	15.01 ± 0.81[a]
Metformin	7.78 ± 1.00[b]	28.35 ± 3.50[b]	43.55 ± 3.13[b]	8.71 ± 0.36[b]
Extract (200 mg/kg bwt)	7.91 ± 1.05[b]	21.51 ± 1.08[b]	44.73 ± 3.00[b]	8.95 ± 0.71[b]
Extract (300 mg/kg bwt)	7.12 ± 1.18[b]	25.90 ± 2.00[b]	30.56 ± 2.10[b]	6.11 ± 0.58[b]

Note: Data are levels of hepatic lipids and plasma total protein and are expressed as mean ± SEM (n = 5).
[a]$p < 0.05$, when compared with normal control group

[b]$p < 0.05$, when compared with diabetic group

Table 4: Plasma NO Level.

Group	NO (μmole/L)	%NO
Normal Control	33.00 ± 0.50	12.41 ± 1.15
Diabetic	52.00 ± 1.75[a]	38.01 ± 1.23[a]
Metformin	35.13 ± 2.13[b]	29.64 ± 1.43[b]
Extract (200 mg/kg bwt)	36.63 ± 1.63[b]	27.24 ± 0.42[b]
Extract (300 mg/kg bwt)	39.50 ± 1.00[b]	24.55 ± 1.09[b]

Note: Data are plasma NO level and are expressed as mean ± SEM (n = 5).
[a]$p < 0.05$, when compared with normal control group

[b]$p < 0.05$, when compared with diabetic group

Discussion

This study investigated the potential of ethanol extract of *C. sativus* fruit in the modulation of the activity of G6Pase/aminotransferases and levels of lipids in tissues of STZ-induced diabetic rats. Hyperglycemia in DM results from increased hepatic gluconeogenesis and reduced glucose uptake in peripheral tissues. The chief and regulatory enzyme of gluconeogenesis is G6Pase. Along with elevated glycogenolysis during fasting, there is increased G6Pase activity in the liver [9]. Thus, glucose 6-phosphate generated from glycogenolysis is released from liver into the circulation for peripheral use. There does not appear to be G6Pase in skeletal muscle; hence, muscle glycogen is not a source of circulating glucose. Glucose-6-phosphatase deficiency (glycogen storage disease, GSD, type Ia) results in hypoglycemia and excessive intracellular accumulation of glucose-6-phosphate [9]. Hypoglycemia may produce lethargy, coma, seizures and brain damage in gluconeogenic and glycogen synthase deficiencies. As a result, there is formation of lactic acid, uric acid and lipids. A second form of the disease (type Ib) has been described. The defect in this form involves the glucose-6-phosphate translocation system that is important in facilitating the movement of the substrate into the microsomal compartment for enzymatic conversion to glucose by G6Pase. The clinical features of types Ia and Ib are similar, but normal enzyme activity is present in type Ib. Hepatomegaly, bleeding diathesis and neutropenia are present. The neurological signs result from chronic hypoglycemia. Recent studies indicate that lactate may be used by the brain as an alternative cerebral metabolic fuel when hypoglycemia is associated with lactic acidosis. Nocturnal intragastric feeding and frequent daytime meals ameliorate most of the clinical and metabolic abnormalities of this condition.

Type I GSD, also known as von Gierke disease, is associated with de novo overproduction of purine as well as gout in childhood or adolescence. Glucose 6-phosphatase deficiency is an autosomal recessive disorder with an incidence of roughly 1 in 100, 000 [28]. Glucose 6-phosphatase (G6Pase) and glucose-6-phosphate transporter (G6PT) together maintain glucose homeostasis. Involvement of either type 1a or 1b GSD results in growth retardation, hypoglycemia, organomegaly, hyperuricemia, lactic acidemia, hyperlipidemia, as well as neutropenia [29]. The neurologic sequelae are secondary to the associated metabolic disturbances. A number of mutations (primarily missense) have been identified, and reliable carrier testing and prenatal diagnosis is now available with mutation analyses of the G6Pase gene (chromosome 17q21) and the G6PT gene (chromosome 11q23). There are experimental models of gene therapy for G6Pase deficiency, with some potential for this disorder [30]. In this study, STZ-induced DM significantly increased G6Pase activity in the plasma as well as liver and kidney. However, the activity of the enzyme was markedly reduced after treatment with ethanol extract of *C. sativus* fruit, an indication that the extract may promote glucose utilization via glycolysis by repressing gluconeogenesis in erythrocytes, hepatocytes and renal corpuscle.

Human ALP (Halp) are found anchored on the cell membrane by glycosylphosphatidylinositol. They are released in the serum by the action of specific phospholipase. It has a half-life of 7 days, and clearance from serum is independent of bile duct patency or functional capacity of the liver. However, the site of degradation of ALP is not known. Serum ALP levels may remain elevated for up to 1 week after the resolution of biliary obstruction.

The mechanism of the increase in ALP in hepatobiliary disorders has been a matter of debate. Studies have shown that it is due to increased enzyme synthesis and not to reduced hepatobiliary excretion of the enzyme. Increased hepatic enzyme activity parallels the rise in serum ALP activity; this occurs primarily due to increased translation of the mRNA of the enzyme (mediated by rising bile acid concentration) and increased secretion of ALP into serum via canalicular leakage into hepatic sinusoid. The mechanism that precipitates its release into systemic circulation has not been elucidated [31]. The results of this study also showed that STZ markedly elevated the activities of ALT and ALP in rat hepatic tissue, but it did not alter the activity of AST in hepatic and cardiac tissues. On the contrary, treatment of the diabetic rats with the medicinal plant extract significantly reduced the hepatic activities of ALT and ALP. In addition, induction of DM with STZ led to significant increase in the level of hepatic lipids (TC, TG and VLDL-C) and plasma NO, while treatment of the diabetic Wistar rats significantly reversed the effect of STZ by markedly reducing hepatic lipids and plasma NO levels. These results are consistent with findings of previous studies [32,33]. The biological effects of medicinal plants have been linked to their bioactive components [34-53].

Conclusion

The results obtained in this study have demonstrated that ethanol extract of *C. sativus* fruit has the potential to modulate the activity of G6Pase/aminotransferases and levels of lipids in tissues of STZ-induced diabetic rats.

References

1. (2012) Centers for Disease Control and Prevention. Diabetes Report Card. Atlanta, GA: Centers for Disease Control and Prevention, U.S Department of Health and Human Services.

2. Onoagbe IO, Esekheigbe A (1999) Studies on the anti-diabetic properties of Uvaria Chamae in streptozotocin-induced diabetic rabbits. Biokemistri 9: 79 - 84.

3. (2011) Centers for Disease Control. National diabetes fact sheet: national estimates and general information on diabetes and prediabetes in the United States.
4. Imperatore G, Cadwell BL, Geiss LS, Saaddine JB, Williams DE, et al. (2004) Thirty- year trends in cardiovascular risk factor levels among U.S adults with diabetes. Am J Epidemiol 160: 531 - 539.
5. (2006) World Health Organisation. The World Health Report 2006: working together for health. Humans; Professional Competence.
6. Abu OD, Ojo I, Ezike TV (2023) Methanol Fraction of Ethanol Extract of Dialium guineense Stem Bark Mitigates STZ-Induced Oxidative Stress in Rat Liver. Biomedical Journal of Scientific and Technical Research 51 (2): 42594-42600.
7. Abu OD, Osime EC, Ngedaa OS (2023) Cardiac Oxidative Status in Diabetic Wistar Rats Exposed to Ethanol Extract of Cucumis sativus Fruit. J Diagnostics and Case Reports 4 (2): 1-5.
8. Abu OD, Ojo I, Awhin EP (2023) Protective Property of Ethanol Extract of *C. sativus* on STZ-Induced Diabetic Rat Pancreas. Biomedical Journal of Scientific and Technical Research 52 (2): 43613-43618.
9. Phibbs B (2007) The human heart: a basic guide to heart disease (2nd Edn.)., Philadelphia: Lippincott Williams & Wilkins Pp: 1.
10. Abu OD, Imafidon KE, Obayuwana HO, Okuofu ED (2018) Phytochemical, proximate, and metal content analysis of citrullus lanatus (watermelon) seeds. FUDMA Journal of Sciences 2(2): 153 -156.
11. Abu OD, Onoagbe IO (2019a) Biochemical effect of aqueous extract of Dialium Guineense stem bark on oxidative status of normal Wistar rats. International Journal of Clinical Biology and Biochemistry 1(2): 15-18.
12. Abu OD, Adeogun EF, Ebhohon SO (2019b) Oral LD50 of total saponins and tannins isolated from Dialium guineense stem bark. European Journal of Experimental Biology 9(2): 11-13.
13. Abu OD, Iyare HE, Ogboi KU (2022a) Cardiac Oxidative Status in CCl4 Exposed Rats Treated with Extracts of Dialium guineense Stem Bark. Global Journal of Scientific Frontier Research 22(01): 1-6.
14. Abu OD, Umar AB, Eiremiokhae CO (2022b) Investigation of the Cardioprotective Capacity of Aqueous Extract of Icacina trichanta Leaves in Rats Exposed to CCl4. Journal of Genetics and Cell Biology 6(1): 322-328.
15. Abu OD, Onoagbe IO, Ohikhuare F (2022c) Nephrotoxic Evaluation of Ethanol Stem Bark Extract of Dialium guineense in Normal Wistar Rats. International Journal of Forensic Medicine 4(2): 19-22.
16. Abu OD, Imafidon KE, Obayuwana O (2020a) Effect of aqueous extract of Anacardium occidentale leaves on blood glucose level and lipid profile of diabetic rats. Global Scientific Journal 8(10): 977-987.
17. Abu OD, Imafidon KE, Obayuwana O (2020b) Ethanol leaf extract of Anacardium occidentale ameliorates alloxan-induced changes on blood glucose level and lipid profile of Wistar rats. IAR Journal of Medical Sciences 1(5): 257-262.
18. Abu OD, Onoagbe IO, Obahiagbon O (2020f) Vitamin contents of extracts of Dialium guineense stem bark. Biomed J Sci and Tech Res 30(2): 23263 -23267.
19. Abu OD, Onoagbe IO, Obahiagbon O (2020g) Analyses of metal and amino acid compositions of aqueous and ethanol stem bark extracts of Dialium guineense. Journal of Biogeneric Science and Research 6(4): 1-3.
20. Reitman S, Frankel S (1957) A colorimetric method for the determination of serum glutamic oxalacetic and glutamic pyruvic transaminases Am J Clin Pathol 28(1): 56-63.
21. Babson LA (1965) Phenolpthalein monophosphate, a new substrate for alkaline phosphatase. In: Abstracts of papers from scientifi c sessions: 17th National Meeting of the American Association of Clinical Chemists Chicago III.
22. Henry RJ, Sobel C, Beckman S (1957) Determination of serum protein by the biuret reaction. Anal Chem 92(149): 1-5.
23. Reiser R, Probstfield JL, Silvers A, Scott LW, Shorney ML, et al. (1985) Plasma lipid and lipoprotein response of humans to beef fat, coconut oil and safflower oil. Am J Clin Nutr 42 (2):190-197.
24. Tietz NW, Finley PR, Pruden EL (1990). Clinical Guide to Laboratory Tests. (2nd Edn.)., W.B. Saunders, Philadelphia PP: 304-306.
25. Friedewald WT, Levy RI, Fredrickson DS (1972) Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. Clin Chem 18 (6): 499-502.
26. Garland RC, Cori CF, Chang HW (1974) Relipidation of phospholipid-depleted microsomal particles with high glucose 6-phosphatase activity. Proc Nat Acad Sci 71 (10): 3805-3809.
27. Marcocci L, Packer L, Droy Lefaix MT, Sekaki A (1994) Antioxidant action of Ginkgo biloba extract EGb 761. Methods in Enzymology 234: 462-475.
28. Chou JY, Matern D, Mansfield BC, Chen YT (2002) Type I glycogen storage diseases: disorders of the glucose-6-phosphatase complex. Curr Mol Med 2 (2): 121-143.
29. Chou JY, Mansfield BC (2007) Gene therapy for type I glycogen storage diseases. Curr Gene Ther 7 (2): 79-88.
30. Marcolongo P, Barone V, Priori G, Pirola B, Giglio S, et al. (1998) Structure and mutation analysis of the glycogen storage disease type 1b gene. FEBS Lett 436 (2): 247 - 250.
31. Vimalraj S (2020) Alkaline phosphatase: Structure, expression and its function in bone mineralization. Gene 754: 144855.
32. Abu OD, Awhin EP, Ifekwe JC (2023) Liver Function Status of Diabetic Wistar Rats Treated with Ethanol Extract of Cucumis sativus Fruit. Biomedical Journal of Scientific and Technical Research 51 (2): 42440-42445.
33. Abu OD, Ohikhuare F, Ezike TV (2023) In vitro Antioxidant Activity of Aqueous and Ethanol Extracts of Cucumis sativus. Journal of Clinical Epidemiology and Public Health 01 (03): 1-6.
34. Abu OD, Onoagbe IO, Ekugum E (2022) Nephrotoxic Evaluation of Aqueous Stem Bark Extract of Dialium guineense in Normal Wistar Rats. Journal of Pharmaceutical and Bio-Medical Sciences 2 (9): 353-357.
35. Abu OD, Onoagbe IO, Ohikhuare F (2022) Nephrotoxic Evaluation of Ethanol Stem Bark Extract of Dialium guineense in Normal Wistar Rats. International Journal of Forensic Medicine 4 (2): 19-22.
36. Abu OD, Ngedaa, OS, Osarhenomase EG (2022) Effect of Extracts of Dialium guineense Stem Bark on Lipid peroxidation Index and Histological Changes in Kidneys of Normal Rats. Forensic Medicine 4 (2): 23-29.
37. Abu OD, Umar A-B, Adekanle E (2022) Cardiotoxic Effect of Aqueous Extract of Dialium guineense Stem Bark in Wistar Rats. East African Scholars Journal of Agriculture and Life Sciences 5 (9): 167-172.
38. Abu OD, Odagwe UB, Ojo AU (2022) Cardiotoxicity of Ethanol Extract of Dialium guineense Stem Bark in Rats. World Journal of Pharmaceutical and Life Sciences 8 (11): 34-39.
39. Abu OD, Okuo AV, Ayele PE (2022) Pancreatotoxic Effect of Aqueous Extract of Dialium guineense Stem Bark in Wistar Rats. International Journal of Novel Research in Life Sciences 9 (5): 31-37.

40. Abu OD, Alegun O, Ojo AU (2022) Pancreatotoxicity of Ethanol Extract of Dialium guineense Stem Bark in Rats. World Journal of Pharmaceutical and Life Sciences 8 (11): 40-45.

41. Abu O D, Iyare H E, Omoruyi I J (2022) Toxic Responses of the Blood of Rats Exposed to Aqueous Extract of Dialium guineense Stem Bark. FUDMA Journal of Science 7 (2): 117 -120.

42. Abu O D, Avenbuan S E, Ayele P (2022) Investigation of the haematotoxicity of ethanol stem bark extract of Dialium guineense in rats. Journal of Clinical and Biomedical Advance 2(1): 1-4.

43. Abu O D, Onoagbe I O, Ekugum E (2022) Hepatotoxicity of Graded Doses of Ethanol Extract of Dialium guineense Stem Bark in Wistar Rats. Journal of Pharmaceutical and Bio-Medical Sciences 2 (9): 347-352.

44. Abu O D, Umar A B, Ajuwa O I (2022) Protective Property of Total Saponins and Tannins of Dialium guineense Stem Bark in CCl4-Induced Cardiotoxicity in Rats. World Journal of Genetics and Molecular Biology 1 (1): 1-6.

45. Abu O D, Umar A B, Eiremiokhae CO (2022) Investigation of the Cardioprotective Capacity of Aqueous Extract of Icacina trichanta Leaves in Rats Exposed to CCl4. Journal of Genetics and Cell Biology 6 (1): 322-328.

46. Abu O D, Imafidon K E, Iribhogbe M E (2015) Biochemical effect of aqueous leaf extract of Icacina trichanta Oliv. on urea, creatinine and kidney oxidative status in CCl4-induced Wistar rats. Nigerian Journal of Life Sciences 5 (1): 85-89.

47. Abu O D, Imafidon K E, Iribhogbe M E (2017) Aqueous leaf extract of Icacina trichanta Oliv. ameliorates CCl4-induced liver toxicity in Wistar rats. Journal of the Nigerian Society of Experimental Biology 17 (3): 107-111.

48. Omoregie F O, Okolie N P, Abu O D (2017) Effects of aqueous extract of Annona muricata leaves on cyanide –induced toxicity in New Zealand Rabbits. Journal of the Nigerian Society of Experimental Biology 16 (4): 141-147.

49. Abu O D, Imafidon K E, Obayuwana H O, Okwudiri N B (2017) Hepatotoxic effect of methanol extract of citrullus lanatus seeds in Wistar albino rats. Journal of the Nigerian Society of Experimental Biology 17 (4): 159-163.

50. Imafidon K E, Obayuwana H O, Abu O D, Enakerakpor O E, Bienose L I, et al. (2018) Proximate Analysis and the Curative Properties of Ipomoea batatas Lam in Phenylhydrazine-induced Anaemic Rats. Journal of the Nigerian Society of Experimental Biology 18 (3): 139-144.

51. Okpiabhele A O, Nwanze E A C, Abu O D, (2018) Therapeutic Potential of Virgin Coconut Oil in Ameliorating Diabetes Mellitus and Hepatotoxicity Using Rattus Norvegicus as Case Study. Asian Journal of Biological Sciences 11 (3): 138-144.

52. Ebhohon S O, Ibeh R C, Ejiofor U E, Abu O D, Osegenna S C (2019) Hepato- and nephro-protective effects of methanol extract of Citrullus lanatus rind in Wistar rats fed with used motor engine oil contaminated feed. FUDMA Journal of Sciences 3 (4): 246-250.

53. Ebhohon S O, Ibeh R C, Ejiofor E U, Abu O D, Chibueze F C (2019) Aqueous extract of Hibiscus Sabdariffa ameliorates cadmium-induced liver and kidney injuries in male Wistar rats. Journal of Society for Experimental Biology of Nigeria 19 (1): 55-59.

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