IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 15, Issue 6 Ver. X (June 2016), PP 97-104
www.iosrjournals.org

Aqueous Leaf Extract of *Dryopteris Dilatata* on STZ - Induced Diabetic Wistar Rats with Associated Hyperlipidemic Ameliorating Property

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Abstract: *The frequency at which diabetes mellitus ravages many societies is amazingly high, and this has resulted to social, economical, financial and worse still health challenges to certain ethnic tribes in Nigeria and to most African communities at large. The study is targeted at examining the glucose lowering effect and possibly associated hypolipidaemic property of Dryopteris dilatata leaf extract in STZ-induced diabetic rats. This study was birthed to assess the effect of Dryopteris dilatata aqueous extract on serum glucose level and lipid profile in STZ-induced diabetes in Wistar rats. However, the phytochemical composition as well as the LD_{50} was examined. Thirty adult (30) Wistar rats weighing between 180- 200g were selected into six (6) groups of five rats each (n=5). Groups 1 and 2 severed as untreated non-diabetic and untreated diabetic controls respectively. Single IP injections of STZ at a dose of 65mg/kg was given to induce diabetes in groups 3, 4, 5, and 6 and were treated with different doses of D. dilatata with the exception of group 3 rats that received a standard diabetic drug (metformin). Body weight and fasting glucose of the animals were routinely checked weekly. After about 30days, the animals were sacrificed, blood samples collected and centrifuge to obtain serum for analysis. Phytochemical analysis indicated the presence of eight bioactive agents such as saponins, steroids, tannins, alkaloids, phenols while some bioactive agents were absent. The LD_{50} was above 4g/kg as a tolerance dose. Body weights were significantly ($p<0.05$) reduced in the STZ untreated diabetic rats compared to control rats while D. dilatata administration at varying dose related manner maintained body weight upon STZ treatment to a near normal value as compared to group 1 (control) and metformin treated rats. D. dilatata caused -28.22 ± 5.03^{a} % decrease in the value obtained for fasting blood glucose when 500mg/kg was administered and -35.85 ± 4.80^{a} % and -44.55 ± 6.56^{a} % respectively with 800mg/kg and 1000mg/kg of D. dilatata. Serum lipid profile were significantly ($p<0.05$) increased in non-treated STZ-induced diabetes rats with D. dilatata significantly ($p<0.05$) reducing these lipid profiles which was dose dependent. In conclusion, this study showed possible potentials of D. dilatata aqueous extract exhibiting hypoglycemic and hypolipidaemic effects.*

Keywords*: Dryopteris dilatata (Dd), Streptozotozin* (STZ), diabetic mellitus, hypolipidaemic, hypoglycaemic

I. Introduction

Diabetes mellitus (DM) is a disease commonly associated with elevated glucose level in blood (hyperglycemia) with the ability to alter metabolism of fats and protein and to a large extent carbohydrates metabolism [1]. In this condition, insulin secretion by the beta-cells of the islet of Langerhans in the pancreas is partially deficient (insulinoplethoric) or absolutely deficient (insulinopenic) or either cells cannot utilize the insulin generated [2, 3]. In 2013, the WHO anticipated that diabetes mellitus would become a major cause of death by the year 2030 [4]. Countries like Nigeria has being with diabetes mellitus as observed from previous studies [5]. Diabetes is accompanied with complications such as decrease cellular uptake of glucose especially by the hepatocytes, weight loss, ketosis, retinopathy and cardiovascular disorders [6]. In addition, there are three traditional symptoms of diabetes mellitus, known as polyuria (excessive urination), polyphagia (excessive hunger) and polydipsia (excessive thirst). Report from research studies has shown that increase in body fat leads to less action of insulin and increases several toxicants in the body.

Until today, diabetes is still an incurable disorder and its management is through the use of oral hypoglycemic agents such as sulphonylureas, glucophages etc [7]. The uses of these oral hypoglycemic substances have remarkably caused changes in ameliorating or prevent complications that might cause damage to health and subsequently death to patience [8]. Currently in Third World countries like Nigeria, the search for suitable herbs with hypoglycemic activities as well as low cost implications has being on the lookout for decades running, since some herbal plants have exhibited promising health benefits in combating certain ailments affecting mankind. One of such herbal plant that is on folk medicinal trial for diabetes in the "Urhobos"

and "Isoko" speaking part of Delta State in Nigeria is *Dryopteris dilatata*, locally known as "Tofatofa". D. dilatata is a deciduous fern which belongs to the family of dryopteridaceae [9]. It possesses dark green tripinnate fronds with the ribs covered in brownish scales [10]. Report from other studies has shown that Dryopteris dilatata can be medicinally applied as an anti-dandruff agent as well as a worm expellant [11].

Dryopteris dilatata is presently being used locally in Olomoro community in Delta State as a tonic for treating diabetes mellitus (DM) and other ailments hence, our interest in checking its anti-diabetic and anti-lipidemic effects on Wistar rats. Although locally this herbal plant has shown some positive and remarkable progress in the control of diabetes in some treated cases, little scientific explanation and claims has been given to its efficacy for which it is being used in this region. More so, accurate dose administration as well as possible side-effects with respect to alteration of biochemical parameters by the extract use might not have being taken into cognizance by these traditional herbalists.

Therefore, it is on these bases that this study attempts to investigate the anti-diabetic effect of *Dryopteris dilatata* and its associated hyperlipidemic properties on STZ-induced diabetes in rats. Furthermore, the procedures employed for this research, attempts to establish scientifically the native claims of *Dryopteris dilatata* as a hypoglycemic substance and its possible capacity to stabilize the lipid profile level in experimental animals.

II. Material and Methods

2.1. Plant Material

Dryopteris dilatata leaves was collected from the wide growing habitat within Olomoro of Isoko south LGA of Delta State and was transported to the Department of Botany, Taxonomy Unit, Delta State University, Abraka where it was identified and authenticated by Harrison Erhenhi the Chief Taxonomist as *Dryopteris dilatata* (Mill). A specimen of *Dryopteris dilatata* was kept and a copy preserved in the herbarium for future reference. The research period was undertaken between the month of August and December, 2015

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2.2. Extract preparation

The leaves were cut off from the stalk and dried in open air at room temperature (29±2ºC), to obtain a constant weight after which it was ground with a blender and sieved to fine powder and made into extracts used for the experiment. Five hundred grams (500g) of the powder was weighed out and soaked in 1000ml of boiled water for 3hrs. Later on, it was then filtered through Whatmann filter paper, No. 40. The filtrate under reduced pressure was concentrated in a vacuum at 30ºC for 30mins using a rotary evaporator (Gallenkamp, UK). The dark-brownish residue obtained was collected but kept cool at 4ºC. Prior to use the substance obtained was constantly reconstituted with distilled water.

2.3. Qualitative and Quantitative Phytochemical Screening of Dryopteris dilatata Aqueous Extract

Twelve bioactive ingredients were investigated in *Dryopteris dilatata* qualitatively and quantitatively for its phytochemical composition. Chemical tests were performed using standard methods to identify the various constitutes [12, 13, 14].

2.4. Experimental animals / grouping

Thirty relatively healthy adult male Wistar rats weighing between 180g-200g were used for the study. The experimental animals were purchased from the Animal House of the Emma-maria Scientific Research Laboratory, Abraka, Delta State, Nigeria. The animals were housed in wooden cages in the Animal House, Faculty of Basic Medical Sciences, Delta State University, Abraka and were organized into six groups of five rats each. They were maintained in normal laboratory condition of room temperature (27±2^{o}C) and a relative humidity of46±6% in a cycle of about 12hours light and 12hour dark. Adequate ventilation was ensured for the animals. The acclimatized of the animals was allowed for a week and during this time frame; they were allowed access to food and water before being randomly divided into different groups. They were fed standard growers mash diet (a product of Top Feed, Sapele, Delta State). On the last day of the acclimatization period, the animals were deprived food for 12- hours. Blood glucose was checked after this period using an ACCUCHEK glucometer and blood was gotten from the tail vein of the rats. The rats with glucose levels of 7.5mmol/L [15] were considered normoglycaemic and used for the study as the normoglycaemic group.

2.5. Ethical Consideration

Before the research conducts, ethical conditions on laboratory animal use were considered and adhered to as postulated by Ward and Elsea [16]. The experimental guidelines were approved by the institution's ethical committee for lab animal use.

2.6. Toxicity test (LD_{50} Studies)

Crude *D. dilatata* extract was administered to different sets of Wistar rats in order to determine the expected LD_{50} using Lorke's method [17]. Different high dose concentration (400mg/kg, 800mg/kg, 1600mg/kg, 2400mg/kg and 4000mg/kg) were given five different groups of six rats each. The animals were monitored for 72hours (3days) for changes in behavior such as itching of whiskers, restlessness and mortality. Main while, the dose that will produce 50% death was noted as well.

2.7. Drug Administration and induction of Diabetes

Streptozotocin (STZ) was reconstituted in cold saline solution (0.9% sodium chloride, pH 7) to get the appropriate concentration that was administered to the rats. The rats were induced with diabetes intraperitoneally by the administration of a single injection dose of 65mg/kg body weight [18, 19]. Forty-eight hours (2days) after induction, diabetes was confirmed with a random blood glucose level of ≥200mg/dl, using the ACCUCHEK glucometer [20].

2.8. Chemicals and reagents used for the study

Streptozotocin (STZ) and chemicals used for this study were of Analytical grade and were purchased from Uche Scientific Co. Ltd. 21, Iga-idunganran Street, Idumota, Lagos State. All the reagents were commercial kits and products of Randox Laboratories Ltd, Antrim, United Kingdom.

2.9. Animal grouping and Treatment

With the exception of group 1 animals, rats in all other groups hither to, were administered STZ intraperitoneally to induce diabetes. The administration of *Dryopteris dilatata* extract (by gastric intubation) and metformin are as appropriated below:

Group 1 (Control): This group of rats did not receive STZ , metformin or *Dryopteris dilatata* but were permitted to access feed and water *ad libitum* for the experimental period.

Group 2 (Diabetic rats): Animals here after were neither treated with metformin nor *Dryopteris dilatata* extract, but was given normal diet and water for the duration carried out above.

Group 3 (Diabetic rats): Rats here were given 500mg/kg of metformin (i.e standard oral hypoglycaemic drug) and hence received feed and water under the same experimental condition.

Group 4 (Diabetic rats): These rats were administered with 500mg/kg extract of *Dryopteris dilatata* and allowed access to feed and water *ad libitum* .

Group 5 (Diabetic rats): Animals in this group collected 800mg/kg extract of *Dryopteris dilatata* and consumed normal feed and water as above.

Group 6 (Diabetic rats): This group was treated with 1000mg/kg extract of *Dryopteris dilatata* and received their routine meal with water for the same duration.

The duration for research period spun between 28-30 days and this entailed the collection of data samples (weight measurements) to termination of experiment. The dose of the metformin administered to the rats was adopted as describe by Wulffelé, *et al*., [21].

2.10. Sample Collection

The animals were starved overnight and were sacrificed by cervical dislocation with each animal dissected to expose the internal organs. Blood was collected by cardiac puncture by means of a 5ml syringes into plain blood sample containers to clot. The blood samples were centrifuged at 4000 rpm for 15 minutes and the serum was collected and stored in a refrigerator at $4^{o}C$ for analysis.

2.11. Biochemical assay

Collected and stored samples were analyzed for serum (HDL)-cholesterol, triglycerides (TG), and total cholesterol (TC) concentrations by enzymatic determination using the kits while low density lipoprotein (LDL) was calculated by using Friedwald calculation [LDL = Total cholesterol – (HDL + TAG/ 5.0) mg/dL] [22].

2.12. Statistical Analysis

The results were expressed as Mean ± SEM and statistical significance of the treatment effect was analysed using the Student's *t*-Test statistics (Fisher`s LSD t-test), one way analysis of variance (ANOVA), followed by post Hoc Fisher's test for multiple comparison, using the software, statistical package SPSS version 21 windows software. The P values was set at < 0.05 and considered significant.

III. Results

2.13. Phytochemical Screening

The phytochemical screening of twelve bioactive ingredients was investigated in the aqueous extract of *Dryopteris dilatata*. Qualitatively, the extract revealed the presence of alkaloids, saponnins, tannins, cardiac glycosides, phenol, steroids, phytosterols and triterpenoids while anthraquinones, flavonoids, terpenoids and phlobatannins were not observed in the aqueous extract of *Dryopteris dilatata*. Upon quantitative analysis, higher amounts were expressed in phenols, saponins and steroids while a moderate quantity was obtained for alkaloids, tannins and phytosterols. Some phytochemicals was not observed in the extract. The result obtained is shown in Table 1 below.

Table 1: Qualitative screening of the aqueous extract of Dryopteris dilatata

Bioactive ingredients	Qualitative Test	Quantitative Test
Alkaloids	++	6%
Saponins	+++	15%
Tannins	++	7.8%
Flavonoids	-	-
Phenols	+++	18.9%
Anthraquinones	-	-
Cardiac glycosides	+	1.1%
Steroids	+++	13.3%
Terpenoids	-	-
Phytosterols	++	6.6%
Phlobatannins	-	-
Triterpenoids	+	0.9%

Keys: (+++) Abundantly present; (++) moderately present; (+) Trace amount; (-) absent.

2.14. LD_{50} Results

Results from Table 2 did not reveal any obvious sign of toxicity in all treatment doses after the extract administration to the experimental animals. All the animals survived after seventy-two (72) hours of observation. The LD_{50} was estimated to be above 4.0g/kg.

Table 2: Acute Toxicity (LD_{50}) of *Dryopteris dilatata*

Treatment Groups	**Number of Death Over number of survival**
Extract, 400mg/kg	0/6
Extract, 800mg/kg	0/6
Extract, 1600mg/kg	0/6
Extract, 2400mg/kg	0/6
Extract, 4000mg/kg	0/6

2.15. Body weight Change upon Dryopteris dilatata administration

Studies have shown that there is a great connection between weight loss and diabetes [23]. In a dose related manner, the administration of the aqueous extract of *Dryopteris dilatata* on hyperglycemic rats (table 3) showed significant ($p<0.05$) improvement in the body weight when compared to the diabetic untreated group (group II). The reduce change in weight as observed in the diabetic untreated rats was greatly improved especially at higher doses of the extract. Hence, *Dryopteris dilatata* treatment at doses of 800mg and 1000mg/kg indicated a statistically non-significant ($p>0.05$) change in weight when compared with the control and metformin administered group (50mg/kg).

Table 3: Effect of aqueous leaves extract of Dryopteris dilatata on the body weight

GROUPS	**Before induction**	**Before Treatment**	**After Treatment**	**% Change before and after treatment**
Group I (Control)	141.40±3.70	140.56±3.59	151.74±2.95	$6.98±1.27^{a}$
Group II (Untreated)	144.56±3.58	133.58±2.52	118.44±3.00	$-12.78±4.17^{c}$
Group III (Metformin)	147.42±1.77	137.50±1.82	140.96±2.73	$2.46±1.73^{b}$
Group IV (500mg/kg Extract)	146.04±1.88	135.20±2.03	131.02±2.70	$-3.19±2.30^{d}$
Group V (800mg/kg Extract)	145.44±2.03	133.18±1.04	135.55±3.36	$1.74±1.70^{b}$
Group VI (1000mg/kg Extract)	139.20±3.20	131.77±2.47	$137.90±3.08^{a}$	$4.45±2.11^{a}$

Values are expressed as Mean ± SEM. Values having the same superscript are not significantly different (P>0.05) from each other. Values that differ in superscripts are significantly different (P<0.05) from control and other groups.

2.16. Blood Glucose level upon (mg/dl) Dryopteris dilatata Administration

High glucose level in blood has being the major symptom in diabetic organisms, hence the effect of Dryopteris dilatata on fasting blood sugar (FBS) was a necessary parameter to determine its hypoglycemic effect for this studies. The result observed from Table 4 shows that the level of glucose in the blood of the diabetic untreated group (group II) was higher than control as well as the other groups. Administration of Dryopteris dilatata at various doses of 500, 800 and 1000mg/kg significantly (p<0.05) reduced the level of glucose when compared with the hyperglycemic untreated group. Observation from results in table 4 also indicated a non-significant value (p>0.05) in glucose level of Dryopteris dilatata at 500mg/kg and 800mg/kg when compared with the standard drug treatment (metformin).

Table 4: Effect of aqueous leaves extract of *Dryopteris dilatata* on glucose level of the animals

Fasting blood glucose level (mg/dl)				
FBS GROUPS	Before induction	After Induction	After Treatment	% Change before and after treatment
Group I (Control)	84.40±6.82	87.60±2.05	89.28±3.85^{c}	1.88±2.01^{c}
Group II (Untreated)	85.00±3.65	288.60±38.85	467.05±17.01^{b}	44.75±9.38^{b}
Group III (Metformin)	87.20±3.92	285.41±12.53	194.50±4.61^{a}	-46.73±11.77^{a}
Group IV (500mg/kg Extract)	91.20±2.78	290.10±30.98	235.22±13.90^{a}	-28.22±5.03^{a}
Group V (800mg/kg Extract)	79.20±5.20	265.33±54.72	195.31±9.13^{a}	-35.85±4.80^{a}
Group VI (1000mg/kg Extract)	88.60±3.01	288.80±30.93	199.80±5.40^{a}	-44.55±6.56^{a}

Values are expressed as Mean ± SEM. Values not having the same superscript differ significantly at P<0.05 while values with the same superscript are not statistically significant P>0.05 from each other.

2.17. Dryopteris dilatata Administration on Lipid Profile

The increase in the cholesterol, triglycerides and low density lipoprotein (LDL) in diabetic untreated rats as revealed in this study was significantly different (p<0.05) when compared to the control, metformin (500 mg/kg) treated group as well as the extract received groups. The administration of aqueous extract of Dryopteris dilatata at different doses (500, 800 and 1000 mg/kg) decreased the levels of total cholesterol, triglycerides and low density lipoprotein to near normal value as observed in the control. Improved level of high density lipoprotein (HDL) and total albumin levels was observed in the extract treated animals, and this was statistically significantly different (p<0.05) when compared with the untreated group II animals.

Table 5: Effect of aqueous leaves extract of *D. dilatata* on the lipid profile of STZ- induced diabetic rats

GROUPS	**Cholesterol**	**Triglyceride**	**HDL**	**LDL**	**Total Protein**
	(mg/dl)				
Group I (Control)	138.06±6.09^{a}	56.82±11.21^{a}	49.32±5.08^{a}	28.18±4.14^{a}	9.18±0.65^{a}
Group II (Untreated)	211.38±12.48^{b}	159.37±19.48^{b}	22.03±5.54^{b}	90.10±9.58^{b}	3.05±1.84^{b}
Group III (Metformin)	157.02±9.43^{c}	99.01±7.22^{c}	45.37±4.62^{a}	36.11±7.43^{a}	8.87±0.99^{a}
Group IV (500mg/kg Extract)	161.94±10.83^{c}	84.73±14.56^{c}	25.70±3.90^{b}	71.65±7.87^{c}	5.80±1.19^{b}
Group V (800mg/kg Extract)	155.55±12.97^{c}	100.98±12.74^{c}	41.80±1.10^{a}	38.34±1.45^{a}	5.43±0.33^{a}
Group VI (1000mg/kg Extract)	144.84±3.33^{a}	99.28±5.24^{c}	47.16±5.30^{a}	37.44±6.81^{a}	6.60±1.20^{a}

Values are expressed as Mean± SEM. Values not having the same superscript differ significantly at P<0.05 while values with the same superscript are not statistically significant P>0.05 from each other.

IV. DISCUSSION

The paramount need of patients who are diabetic is to attain as well as sustain normal blood sugar level. Complications that emanate from diabetes are largely due to poor management. However, in developing countries like Nigeria, poor level of education, poor nutritional intake and access to orthodox medication, inadequate health facilities tend to escalate the problems of diabetes mellitus [19]. Over the years, herbal plants have shown positive efficacy in the treatment and management of ailments such as diabetes mellitus, high blood pressure, and atherosclerosis e.t.c [24]. This has lead to a paradigm shift in the use of orthodox drugs to herbal drugs which are thought by most local people to be relatively less expensive, time saving and safer [25, 26]. The aqueous leaf extract of *Dryopteris dilatata* was assayed to evaluate its potentials in the management of diabetes

and associated complications. The preliminary phytochemicals investigation of twelve bioactive ingredients in the plant extracts revealed the presence of bioactive compounds like phenols, tannins, saponins, cardiac glycosides, steroids, terpenoids, phytosterols and alkaloids (Tables 1). Other ingredients such as triterpenoids, anthraquinones, phlobatannins and flavonoid were not revealed in the aqueous extract of *Dryopteris dilatata*. The absence of these phytochemicals may not be a minus for the medical efficacy of *Dryopteris dilatata* but this might be due to the fact that variations may sometimes occur in bio-compounds grown in different climatic environment and soil types [27]. Although studies from previous researches have revealed the presence of similar compounds in this class of plants [28], it was essential for reconfirmation in other to relate its traditional therapy in the management and treatment of other ailments [29]. The presence of a high amount of saponin (15%) suggests the ability of the plant to possess antihypercholesterol, hypotensive and cardiac depressant properties [30]. Also, alkaloid which is effective as a detoxifying and antihypertensive agent [31] was observed in the plant extract. Flavanoids, sterols, triterpenoids, alkaloids and phenolics are known to be bioactive anti-diabetic principles [32]. Phenolic compounds which play important role as dietary antioxidants for preventing oxidative damage are also found to be effective anti-hyperglycemic agents [33, 34]. It was not out of context to observe that flavonoids were not found in the aqueous extract of *Dryopteris dilatata*. Flavonoids contribute to the brilliant multi color of most plants and since the leaves of the plant are solely greenish in colour, it is suggestive that this ever green herb might be devoid of flavonoids [14].

Prior to animal treatment with Dryopteris dilatata, the LD_{50} of the extract was ascertained in other to avoid extract toxicity. Observation from Table 2 indicated that there was neither death recorded nor any observable pathological changes seen in animals dosed with 400, 800, 1600, 2400 and 4000 mg/kg of the aqueous extract, thus 4000 mg/kg was considered as tolerated dose according to the method of Lorke, [17]. Previous research work, has revealed that any substance whose LD_{50} is above 1000 mg/kg is regarded relatively safe [35]. Similarly, an extract with LD_{50} of above 3000 mg/kg has being regarded as safe by WHO [36].

Blood glucose measurement or determination is the most relevant biomarker used in monitoring of diabetes clinically and experimentally [37]. In this current research study, the significant increase ($p<0.05$) in blood glucose level upon treatment with STZ is an indication that diabetes was induced in the rats (Table 4). The diabetic effect of STZ has been associated to cytotoxicity by free radical generation (e.g. OH^{-}) in pancreatic β-cell, which damages a great number of these β-cells causing a decrease in insulin secretion hence, resulting in elevated blood glucose within a short period of time [19]. The administration of metformin (500mg/kg) as the standard treatment dose, statistically induced a significant ($p< 0.05$) decrease in blood glucose upon STZ-induced diabetic rats when compared with the diabetic non-treated group in Table 4. Treatment with metformin has been demonstrated caused increase sensitivity of peripheral tissues to insulin hormone thereby enhancing the uptake of glucose by such tissues. Metformin translocates glucose transporters such as GLUT4 found in the muscles and adipose tissues, to increase glucose uptake and blocking the release of free fatty acids into circulation [38].

Results from Table 4 statistically confirms that upon aqueous extract of *Dryopteris dilatata* treatment at various levels (400, 800 and 1000mg/kg), the extract induced a significant ($p<0.05$) decrease in blood glucose as well when compared with that induced by the diabetic non treated control group. This trend, was similar to that observed by the standard drug (metformin) used. Although, the mechanism of action of *Dryopteris dilatata* extract exhibiting anti-diabetic activity is equivocal, it can be speculated that the extract may have enhanced the release of insulin by depolarization of the cell membrane, radical scavenging (due to the presence of phenol) as well as the stimulation of calcium uptake, an essential step in insulin secretion [39].

Both lipid profile and body fat has been shown to be relevant signs for metabolic alterations in diseases such as hypertension, dyslipidaemia, diabetes, cardiovascular diseases etc. Any alteration in the level of lipids in the body makes organisms manifest complications in relation to these diseases [7]. Statistically significant difference ($p< 0.05$) in TAG was found between diabetes mellitus induced non treated group (group II) and the treatment administered groups (Table 5). The increase in the level of triglyceride of diabetic group 2 rats may be as a result of insulin deficiency. Under normal condition, insulin stimulates lipoprotein lipase and TAG hydrolysis; hence the insulin deficiencies in diabetic state, increase blood TAG as a result of hepatic lipase decrease or inactivation [39]. Also the concentrations of TAG in serum increased in diabetic rats because of increase production of VLDL and its reduced clearance[7]. Administration of 500mg/kg of metformin and aqueous extract of Dryopteris dilatata (400, 800 and 1000mg/kg body weight) reduced triglycerides in serum of STZ-induced diabetic rats thereby preventing further complication that aggravates the disease condition. The possible explanation for this hypotriglyceridemia action may be as a result of the inhibition of endogenous glucose production or interference with GIT glucose absorption by the extract [40]. Further explanation regarding the mechanism of action of aqueous extract of Dryopteris dilatata at 800 and 1000mg/kg body weight may be that the extract enhanced enzymes activity involved in bile production thereby leading to decrease in serum cholesterol and triglycerides [41]. More so, since the aqueous extract of Dryopteris dilatata possesses

phenols, steroids and cardiac glycosides, lipid lowering effect might be due to the actions of these bioactive compounds found in the extract [42, 43].

In this study (Table 5), the low and high concentration of HDL and LDL observed respectively in diabetic rats when compared to control rats, was in accordance with the reports of several studies demonstrating that a rise in glucose level on induction of diabetes, results in a corresponding increase in plasma lipids [44, 45, 46]. Previous report demonstrated that hyperlipidemia is a known complication associated with diabetes mellitus thereby generating elevated levels of cholesterol, triglycerides and other lipoproteins [46, 47]. It was elucidated that the elevated serum lipids in diabetes is due to the increased free fatty acids mobilization from peripheral adipose tissues as a result of inhibition of the hormone sensitive lipase [48]. Thus, the marked hyperlipidemia seen in diabetic rats may be considered as the aftermath of uninhibited actions of lipolytic hormones in adipocytes [49]. Treatment of diabetic rats with the aqueous extract of *Dryopteris dilatata* caused a significant ($P < 0.05$) decrease in serum and liver lipids, showing its hypolipidemic effect. It is necessary to state that the presence of bioactive ingredients like alkaloids, saponins, and polyphenols found in the extract might have great influence in the reduction of serum lipid level in animals. This however is in line with results obtained from previous studies [50, 51].

V. Conclusion

The proposal that diabetes mellitus would be amongst the leading disease in the near future is not farfetched. Studies have revealed that elevated glucose level in the blood alongside body fat and lipid profiles are responsible for increase prevalence of this disease. In accordance to Pouwer and Hermanns proposition [52], the management of diabetes should address primarily three main areas: prevention of hyperglycemia and associated complications, prevention of hypoglycemia and maintenance of a relatively healthy life style of diabetic patients. This present study has shown that *Dryopteris dilatata* upon STZ-induced diabetes, has hypoglycaemic and hypolipidaemic potentials that might be able to ameliorate possible complications associated with diabetes mellitus, such as atherosclerosis. However, this work did not explore the mechanisms of action of the extract since the sites of intervention in biochemical processes of diabetes is diverse. This study further recommends future examination of the extract on renal function and electrolyte threshold as well as the glycermic index determination of *Dryopteris dilatata* extract.

Acknowledgment

The authors wish to thank the director and laboratory scientist of Mr Ewhre Lawrence of Emma-maria Scientific Research Laboratory, Abraka, Nigeria; for allowing we use their facilities to conduct the analysis. Special thanks to Prof. I. Onyesom of the Department of Medical Biochemistry, Delsu Abraka, for providing the technical know-how.

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