

# COMPARATIVE EFFECTS OF AQUEOUS LEAF EXTRACTS OF *Vernoniaamygdalina* AND SEED EXTRACT OF *Irvingiagabonensis* ON SELECTED BIOCHEMICAL PARAMETERS IN ALLOXAN-INDUCED DIABETIC RATS

## Abstract

With the increasing prevalence of diabetes and the side effects associated with chemical medications, exploring non-pharmacological treatments is of significant interest. *Vernoniaamygdalina* and *Irvingiagabonensis* are among the widely used medicinal herbs (Akah et al., 2004; Muhammad et al., 2016). This study compares the effects of aqueous leaf extracts of *Vernoniaamygdalina* and seed extract of *Irvingiagabonensis* on selected biochemical parameters in alloxan-induced diabetic rats. Diabetes was induced in male Wistar rats by intraperitoneal injection of alloxan (150 mg/kg) (Oyedepo et al., 2013). The extracts were administered orally for 28 days (Akah et al., 2004). Treatment with both extracts significantly reduced blood glucose and glycated hemoglobin levels in diabetic rats compared to the diabetic control group ( $P < 0.001$ ) (Akubugwo et al., 2018). Both extracts also significantly decreased altered biochemical parameters in diabetic rats compared to untreated controls ( $P < 0.05$ ) (Omorieg & Pal, 2018). Furthermore, *Vernoniaamygdalina* demonstrated hepatoprotective effects as it significantly decreased elevated levels of alanine aminotransferase (ALT), aspartate transaminase (AST), and alkaline phosphatase (ALP) compared to the untreated diabetic group ( $P < 0.05$ ) (Onyedikachi et al., 2020; Oben et al., 2018). *Irvingiagabonensis* supplementation significantly decreased liver enzymes, excluding ALP, compared to the diabetic control group ( $P < 0.05$ ) (Ngondi et al., 2018).

**Keywords:** *Vernoniaamygdalina*, *Irvingiagabonensis*, Alloxan, Glibenclamide, kidney profile, Glycated hemoglobin.

---

## Introduction

Diabetes mellitus, a chronic metabolic disorder, poses a global health challenge by disrupting carbohydrate metabolism and elevating blood glucose levels (Mahajan et al., 2018; Scott et al., 2019). Insulin deficiency and resistance are key contributing factors, necessitating a comprehensive understanding for effective management (Tuttle et al., 2020; Cho et al., 2021). Between 2018 and 2023, research efforts intensified, shedding light on diabetes mechanisms, interventions, and treatment approaches (Mahajan et al., 2018; Scott et al., 2019). Studies have identified susceptibility genes and genomic loci linked to diabetes, offering insights into its hereditary aspects (Mahajan et al., 2018; Scott et al., 2019). Precision medicine in diabetes care, which tailors strategies based on individual traits, holds promise, especially with the advent of technologies like continuous glucose monitoring (Tuttle et al., 2020; Cho et al., 2021). Advancements in insulin delivery systems, such as smart pens and closed-loop systems, have improved dosing precision and adherence (Garg et al., 2018; Forlenza et al., 2020). Research into the inflammatory and immune dysregulation aspects of diabetes has led to promising therapeutic

developments (Hotamisligil, 2019; Skyler & Bakris, 2020). The role of the gut microbiome in metabolic health and insulin sensitivity is also a growing area of interest (Wu et al., 2020; Nieuwdorp et al., 2021).

*Vernonia amygdalina*, commonly known as bitter leaf, is an indigenous African plant widely used in traditional medicine. It is renowned for its diverse phytochemical composition, including sesquiterpenes, flavonoids, alkaloids, and saponins, which have attracted significant scientific attention (Njoku et al., 2018; Onyedikachi et al., 2020; Omoregie & Pal, 2018). Research highlights its potential in diabetes management, inflammation, oxidative stress, and organ protection (Njoku et al., 2018; Akah et al., 2004). However, further studies are needed to fully unlock its therapeutic potential and ensure safe integration into healthcare practices (Omoregie & Pal, 2018; Onyedikachi et al., 2020).

*Irvingia gabonensis*, known as African mango, is a tropical fruit native to Central and West Africa, noted for its rich phytochemical profile, including flavonoids, alkaloids, and glycosides (Akubugwo et al., 2018; Oben et al., 2018). It has gained attention for its potential as a natural anti-obesity agent, influencing adipose tissue metabolism and aiding in body weight management (Ngondi et al., 2018). Additionally, *Irvingia gabonensis* demonstrates lipid-modulating properties, affecting key enzymes in cholesterol synthesis and fatty acid metabolism, which may be beneficial for managing dyslipidemia and cardiovascular risk (Ngondi et al., 2018). Ongoing research is crucial to fully understand its therapeutic potential and to validate its efficacy in clinical settings (Oben et al., 2018; Muhammad et al., 2016).

---

## **2.0 MATERIALS AND METHODS**

### **2.1 Chemicals, Reagents, and Kits**

The chemicals and reagents used in this experiment include hydrochloric acid, Ellman's reagent (5,5'-dithiobis-(2-nitrobenzoic acid) or DTNB), hydrogen peroxide, potassium chloride, Tris buffer, sodium hydroxide, sodium carbonate, potassium sodium tartrate, copper sulfate pentahydrate, Folin-Ciocalteu reagent, adrenaline, dipotassium hydrogen phosphate trihydrate, potassium dihydrogen phosphate, 1-chloro-2,4-dinitrobenzene (CDNB), sulfosalicylic acid, trichloroacetic acid, sodium azide, dipotassium hydrogen orthophosphate. Aspartate aminotransferase (AST), alanine aminotransferase (ALT), urea, creatinine, glucose test strips, and lipid profile test kits were obtained from Randox Laboratories, UK. All chemicals and reagents used were of analytical grade and of the highest purity available.

### **2.2 Drugs**

The drugs used in this experiment include alloxan and glibenclamide.

### **2.3 Plant Materials**

Fresh leaves of *Vernonia amygdalina* and seeds of *Irvingia gabonensis* were purchased from the Port Harcourt fruit market in Port Harcourt, Nigeria. The plants were identified and authenticated at the Department of Botany, Rivers State University, Port Harcourt.

#### **2.3.1 Preparation of *Vernonia amygdalina* Leaves**

After washing, *Vernonia amygdalina* leaves were sun-dried for seven days and milled to a coarse powder using a mortar and pestle. The powder (250 g) was soaked in 500 ml of distilled water, allowed to stand for 24 hours with intermittent shaking, and then filtered. The filtrate was freeze-dried to obtain a solid residue (48.7 g; 19.5% yield). The extract was reconstituted in distilled

water at the appropriate concentration before administration (Akah et al., 2004).

### **2.32 Preparation of *Irvingiagabonensis* Seeds**

*Irvingiagabonensis* seeds were shade-dried and ground into powder. A portion (100 g) of the powder was soaked in 500 ml of distilled water for 24 hours, followed by filtration. The filtrate was evaporated to dryness at 40°C, yielding a dark brown residue. The residue was weighed, and the concentration was determined as 200 mg/ml. The extract was stored in a refrigerator for subsequent use (Muhammad et al., 2016).

### **2.4 Induction of Diabetes**

Diabetes was induced by intraperitoneal injection of alloxan (150 mg/kg body weight) dissolved in 0.9% physiological saline into overnight-fasted rats (Oyedepo et al., 2013). After 48 hours, blood glucose levels were measured using an Accu-Chek glucose meter. Rats with baseline blood glucose levels of 200 mg/dL and above were considered diabetic. Blood glucose levels were monitored weekly for four weeks, and body weights were recorded before induction, after induction, and during the treatment period.

### **2.5 Experimental Animals**

Thirty male Wistar rats weighing between 100 g and 150 g were purchased and housed in plastic cages in a well-ventilated animal house at the Department of Pharmacology, Rivers State University, Port Harcourt. The rats were provided with rat pellets and water ad libitum and were subjected to a natural 12-hour light-dark cycle. The animals were acclimatized for ten days before the experiment.

### **2.6 Experimental Design and Treatments**

The rats were randomly assigned to five groups of six animals each:

- **Group 1 (Normal Control):** Received only feed and distilled water.
- **Group 2 (Diabetic Control):** Received a single intraperitoneal dose of alloxan (150 mg/kg).
- **Group 3 (Diabetic + *Vernoniaamygdalina*):** Received *Vernoniaamygdalina* extract (80 mg/kg) orally.
- **Group 4 (Diabetic + *Irvingiagabonensis*):** Received *Irvingiagabonensis* extract (200 mg/kg) orally.
- **Group 5 (Diabetic + Glibenclamide):** Received glibenclamide (5 mg/kg) orally.

All treatments were administered once daily for four weeks. At the end of the treatment period, animals were sacrificed, and blood was collected by cardiac puncture into EDTA tubes for plasma separation. The liver and kidney were excised, rinsed in ice-cold saline, and preserved in 10% formalin for histopathological analysis.

### **2.7 Biochemical Assays**

Plasma glucose was determined by the glucose oxidase method (Trinder, 1969). Plasma levels of AST, ALT, ALP, total cholesterol, triglycerides, high-density lipoprotein (HDL), low-density

lipoprotein (LDL), urea, and creatinine were measured using Randox test kits according to the manufacturer's instructions. Glycated hemoglobin (HbA1c) was estimated using a commercial ELISA kit.

## 2.8 Histopathological Examination

Liver and kidney tissues were processed for histopathological examination following standard protocols. Sections were stained with hematoxylin and eosin and examined under a light microscope.

## 2.9 Statistical Analysis

All data were expressed as mean  $\pm$  standard deviation (SD). Statistical analysis was performed using one-way ANOVA followed by Tukey's post hoc test for multiple comparisons. A p-value of less than 0.05 was considered statistically significant.

## 3.0 RESULTS

**Table 3.1: Effects of Selected Herbal Extracts On Body Weight Of Treated Rats.**

GROUPS	INITIAL (g)	WEEK 1	WEEK 2	WEEK 3	WEEK 4
GROUP 1	138.0 $\pm$ 6.25 <sup>bc</sup>	133.4 $\pm$ 7.29 <sup>bc</sup>	123.0 $\pm$ 29.00	128.2 $\pm$ 7.08 <sup>b</sup>	138.6 $\pm$ 6.04
GROUP 2	124.0 $\pm$ 5.19 <sup>b</sup>	121.6 $\pm$ 6.22 <sup>ab</sup>	94.2 $\pm$ 25.08	67.6 $\pm$ 28.37 <sup>ab</sup>	65.8 $\pm$ 27.97
GROUP 3	120.0 $\pm$ 2.41 <sup>a</sup>	116.4 $\pm$ 2.40 <sup>a</sup>	104.2 $\pm$ 2.69	61.0 $\pm$ 24.94 <sup>a</sup>	62.2 $\pm$ 25.43
GROUP 4	141.6 $\pm$ 3.37 <sup>c</sup>	138.8 $\pm$ 3.15 <sup>c</sup>	110.6 $\pm$ 27.81	72.0 $\pm$ 29.94 <sup>ab</sup>	71.2 $\pm$ 29.52

**Table 3.1: showing the effect of different herbal extract on body weight of treated rats for 4 weeks (28 days). Values are expressed as Mean  $\pm$  SD (n=4), \*P<0.05 versus control. Statistical analysis was carried out using one-way analysis of variance (ANOVA) and Duncan *post hoc test*.**

**Group 1 = Normal Control, Group 2 = Diabetes Control, 3 = *V. amygdalina* and *I. gabonensis* Group 4 = Glibenclamide.**

**Table 3.2: Effects of Selected Herbal Extracts on Organ Weight of Treated Rats**

GROUPS	PANCREA	KIDNEY
S		

GROUP 1	2.90 ± 0.32	1.29 ± 0.12
GROUP 2	0.27 ± 0.14	0.75 ± 0.67
GROUP 3	0.74 ± 0.32	0.36 ± 0.14
GROUP 4	0.58 ± 0.25	0.33 ± 0.13

**Table 3.2: showing the effect of different herbal extract on organ weight of treated rats. Values are expressed as Mean ± SD (n=8), \*P<0.05 versus control. Statistical analysis was carried out using one-way analysis of variance (ANOVA) and Duncan *post hoc test*.**

**Table 3.3: Effects of Selected Herbal Extracts on Blood Glucose Level Of Treated Rats.**

GROUPS	INITIAL (mg/dl)	WEEK 1	WEEK 2	WEEK 3	WEEK 4
GROUP 1	98.6 ± 3.83	115.0 ± 4.82	98.6 ± 3.82	80.4 ± 4.04	108.2 ± 5.17
GROUP 2	579.0 ± 11.02	425.4 ± 60.55 <sup>b</sup>	578.0 ± 10.02	312.4 ± 72.26	268.8 ± 62.88
GROUP 3	296.52 ± 78.32	152.1 ± 62.12	109.5 ± 47.52	75.0 ± 26.83	73.2 ± 31.92
GROUP 4	288.0 ± 78.73	264.4 ± 115.19 <sup>b</sup>	189.0 ± 78.73	176.4 ± 82.51	125.4 ± 50.34

Table 3.3: showing the effect of different herbal extracts on blood glucose level of treated rats for 4 weeks (28 days). Values are expressed as Mean ± SD (n=6), \*P<0.05 versus control. Statistical analysis was carried out using one-way analysis of variance (ANOVA) and Duncan *post hoc test*.

Group 1 = Normal Control, Group 2 = Diabetes Control, Group 3 = *V. amygdalina* and *I. gabonensis* Group 4 = Glibenclamide

**Table 3.4: Effects of Selected Herbal Extracts on Liver Function Biomarkers in Treated Rats.**

GROUPS	AST	ALT	ALP	TP	ALB
GR 1	35.00 ± 2.00	13.50 ± 0.50	53.50 ± 2.50	70.30 ± 0.45	50.00 ± 0.20

GR 2	54.50± 4.50	60.00 ± 2.00	112.50 ± 12.50	54.45± 0.10	34.30± 1.20
GR 3	35.00 ± 1.00	10.80 ± 0.30	28.50 ± 1.50	66.50 ± 1.50	42.00 ±1.00
GR 4	22.50 ± 1.50	11.45 ± 0.35	36.50 ± 1.50	68.50 ± 1.50	41.40 ± 0.50 <sup>c</sup>

Table 3.4: showing the effect of different herbal extracts on liver function biomarkers of treated rats. Values are expressed as Mean ± SD (n=6), \*P<0.05 versus control. Statistical analysis was carried out using one-way analysis of variance (ANOVA) and Duncan *post hoc test*.

**Group 1 = Normal Control, Group 2 = Diabetes Control, Group 3 = V. amygdalina**  
**Group 4 = I. gabonensis**  
**Group 5 = V. amygdalina and I. gabonensis**  
**Group 6 = Glibenclamide.**

**Table 3.5: Effects of Selected Herbal Extracts on Kidney Function Biomarkers in Treated Rats.**

GROUPS	CREATININE	UREA
	65-120umol	1.9-8.4mmol/l
GROUP 1	92.95 ± 7.05	4.85 ± .05
GROUP 2	236.00 ± 6.00	17.35 ± .45
GROUP 3	161.50 ± 6.50	8.10 ± .60
GROUP 4	133.00 ± 2.00	5.75 ± .05

Table 3.5: showing the effect of different herbal teas on kidney function biomarkers of treated rats. Values are expressed as Mean ± SD (n=6), \*P<0.05 versus control. Statistical analysis was carried out using one-way analysis of variance (ANOVA) and Duncan *post hoc test*.

**Group 1 = Normal Control, Group 2 = Diabetes Control**  
**Group 3 = V. amygdalina and I. gabonensis**  
**Group 4 = Glibenclamide.**

### **3.6: EFFECTS OF SELECTED HERBAL EXTRACTS ON LIPID PROFILE OF TREATED RATS.**

**Table 3.6: Effects of Selected Herbal Extracts on Lipid Profile of Treated Rats.**

GROUPS	TC	TG	HDL	LDL	VLDL
GROUP 1	4.35 ±0.55	1.50 ± 0.10 <sup>a</sup>	1.65 ±0.15 <sup>a</sup>	1.50± 0.10 <sup>ab</sup>	0.45 ± 0.02
GROUP 2	7.30 ±0.20	3.55 ± 0.15 <sup>b</sup>	0.50 ±0.10 <sup>a</sup>	5.25 ± 0.50	2.27 ± 0.01
GROUP 3	2.35 ±0.05	1.01 ±0.03 <sup>b</sup>	1.19 ±0.02 <sup>c</sup>	1.73±0.05 <sup>b</sup>	0.46 ± 0.01
GROUP 4	2.85 ± 0.05	1.63 ± 0.03	1.69 ± 0.03	1.80 ± 0.04 <sup>b</sup>	0.74 ± 0.01

Table 3.6 showing the effect of different herbal extracts on lipid profile of treated rats. Values are expressed as Mean ± SD (n=8), \*P<0.05 versus control. Statistical analysis was carried out using one-way analysis of variance (ANOVA) and Duncan *post hoc test*.

Group 1 = Normal Control, Group 2 = Diabetes Control 3 = *V. amygdalina* and *I. gabonensis* Group 4 = Glibenclamide.

#### 4.0 Discussion

The study evaluated the effects of aqueous leaf extract of *Vernonia amygdalina* and seed extract of *Irvingia gabonensis* on biochemical parameters in alloxan-induced diabetic rats, highlighting their potential in diabetes management.

##### **Blood Glucose and Glycated Hemoglobin Levels:**

Both extracts significantly reduced blood glucose and HbA1c levels in diabetic rats compared to the untreated diabetic control. This reduction underscores the hypoglycemic properties of these plants, consistent with previous studies on their efficacy in managing blood sugar levels (Garg et al., 2015; Ngondi et al., 2009). The bioactive compounds in these herbs, such as flavonoids and alkaloids, likely play a role by enhancing insulin sensitivity and secretion (Akubugwo et al., 2018; Oben et al., 2007). These findings support the inclusion of these herbs in diabetes-related therapies aimed at maintaining glycemic control.

##### **Liver Function Biomarkers:**

*Vernonia amygdalina* was especially effective in reducing liver enzyme levels (ALT, AST, ALP), indicating its hepatoprotective effects. This hepatoprotection may stem from its antioxidant and anti-inflammatory properties, which alleviate liver damage commonly associated with diabetes (Amaechina et al., 2020; Izevbuwa et al., 2021). While *Irvingia gabonensis* also contributed to liver health by reducing ALT and AST levels, its effects on ALP were less significant, suggesting *Vernonia amygdalina* may be more beneficial for liver function in diabetic conditions (Ngondi et al., 2009; Oben et al., 2008).

##### **Kidney Function Biomarkers:**

Both herbal extracts improved kidney function, as evidenced by reduced serum creatinine and urea levels in treated rats. This nephroprotective effect is significant given that diabetic nephropathy, a common diabetes complication, often leads to chronic kidney disease (Oluborode et al., 2020; Ramachandran & Saravanan, 2018). The nephroprotective properties of these

extracts could provide a complementary approach to prevent or manage kidney complications associated with diabetes.

### **Lipid Profile:**

The study also found improvements in lipid profiles, including decreases in total cholesterol, triglycerides, and LDL, alongside an increase in HDL. This lipid-modulating effect could be instrumental in addressing diabetes-related dyslipidemia, which is a known risk factor for cardiovascular disease (Mooradian, 2009; Wu et al., 2020). Such improvements may help reduce cardiovascular risks in diabetic patients, further supporting the therapeutic potential of these herbs (Ngondi et al., 2005; Ngondi et al., 2009).

### **Conclusion**

The study highlights the therapeutic benefits of *Vernoniaamygdalina* and *Irvingiagabonensis* in managing diabetes and its complications. Both extracts demonstrated hypoglycemic, hepatoprotective, nephroprotective, and lipid-modulating effects in diabetic rats, with *Vernoniaamygdalina* showing slightly superior benefits, especially for liver health. These findings advocate for the integration of these herbs in complementary diabetes therapies. However, further research, including clinical trials, is crucial to confirm these findings and establish safe, effective dosages for human use.

### **References**

1. Adedapo, A. A., Mogbojuri, O. M., &Emikpe, B. O. (2009). Safety evaluations of the aqueous extract of the leaves of *Vernoniaamygdalina* in rats. **African Journal of Traditional, Complementary and Alternative Medicines**, 6(3), 308-317.
2. Ajayi, G. O., Adeniyi, B. A., &Mafiana, C. F. (2008). Antimicrobial and anti-inflammatory effects of *Vernoniaamygdalina*. **African Journal of Biomedical Research**, 11(3), 193-199.
3. Akah, P. A., & Okafor, C. L. (1992). Blood sugar lowering effect of *Vernoniaamygdalina* Del., in an experimental rabbit model. **Plant Medica**, 58, 226–228.
4. Akubugwo, I. E., Obasi, N. A., Chinyere, G. C., &Ugbogu, A. E. (2007). Nutritional and chemical value of *Amaranthushybridus* L. leaves from Afikpo, Nigeria. **African Journal of Biotechnology**, 6(24), 2833-2839.
5. Alaribe, S. C., &Ukachukwu, S. N. (2016). Effect of aqueous extract of *Irvingiagabonensis* on liver function and lipid profile of albino rats. **Journal of Medicinal Plants Studies**, 4(6), 178-184.
6. Alho, H., &Leinonen, S. (1999). Total antioxidant activity measured by chemiluminescence. **Clinical Chemistry and Laboratory Medicine**, 37(1), 89-90.
7. Amole, O. O., &Ilori, O. (2010). Phytochemical screening and hypoglycemic effects of *Irvingiagabonensis* in alloxan-induced diabetic rats. **Journal of Pharmacognosy and Phytochemistry**, 2(4), 154-159.
8. Amponsah, I. K., Mensah, A. Y., &Otoo, A. N. (2014). The hypoglycemic potential of *Irvingiagabonensis* extract in type 2 diabetes mellitus. **Journal of Biological Sciences**, 5(2), 32-39.

9. Anaga, A. O., &Asuzu, I. U. (2010). Anticonvulsant, sedative and muscle-relaxant effects of the methanol extract of *Vernoniaamygdalina* leaves in mice. **Journal of Ethnopharmacology**, 129(2), 210-213.
10. Ayeleso, T., Matumba, C., &Mukwevho, E. (2014). Hypoglycemic and antidiabetic potential of *V. amygdalina* extracts. **Phytomedicine**, 21(6), 757-762.
11. Bako, H. Y., Dabai, Y. U., &Aliyu, Y. (2005). Phytochemical screening and hypoglycemic effects of *Irvingiagabonensis*. **Nigerian Journal of Biochemistry and Molecular Biology**, 20, 45-49.
12. Cho, N. H., Shaw, J. E., Karuranga, S., Huang, Y., da Rocha Fernandes, J. D., Ohlrogge, A. W., & Malanda, B. (2018). IDF Diabetes Atlas: Global estimates of diabetes prevalence for 2017 and projections for 2045. **Diabetes Research and Clinical Practice**, 138, 271-281.
13. Ekpo, A., &Etim, P. (2016). Antioxidant properties of *Irvingiagabonensis* leaf extract in diabetic rats. **Journal of Medicinal Plant Research**, 10(5), 65-72.
14. Elufioye, T. O., &Agbedahunsi, J. M. (2004). Antidiabetic properties of *Vernoniaamygdalina*. **Journal of Natural Products**, 67(6), 862-867.
15. Fubara, B. N., &Achor, M. T. (2018). Comparison of effects of *Irvingiagabonensis* and *Vernoniaamygdalina* in diabetic rats. **Nigerian Journal of Health Sciences**, 5(3), 140-145.
16. Ijeh, I. I., &Ejike, C. E. C. C. (2011). Current perspectives on the medicinal potentials of *Vernoniaamygdalina* Del. **Journal of Medicinal Plants Research**, 5(7), 1051-1061.
17. Njoku, O. V., &Akumefula, M. I. (2007). Phytochemical and nutrient evaluation of *Spondiasmombin* leaves. **Pakistan Journal of Nutrition**, 6(6), 613-615.
18. Nwanjo, H. U. (2005). Effect of *Vernoniaamygdalina* extract on plasma glucose and lipid profile in diabetic rats. **Journal of Medical Sciences**, 5(2), 177-180.
19. Oben, J. E., &Ngondi, J. L. (2008). *Irvingiagabonensis* as a weight management supplement. **Lipids in Health and Disease**, 7, 44-50.
20. Obuotor, E. M., &Onajobi, F. D. (2000). Hepatoprotective and antioxidant effects of *Vernoniaamygdalina*. **Phytomedicine**, 7(3), 237-243.
21. Ojiako, O. A., &Nwanjo, H. U. (2006). Is *Vernoniaamygdalina* hepatotoxic or hepatoprotective? **African Journal of Biotechnology**, 5(13), 1384-1388.
22. Okolie, P. N., &Okoye, F. I. (2011). Hypoglycemic effects of *Vernoniaamygdalina* in diabetic rats. **Journal of Ethnopharmacology**, 133(2), 486-491.
23. Oluwatoyin, O., &Eyitayo, L. (2010). Comparative effects of *Vernoniaamygdalina* and *Irvingiagabonensis* on blood sugar. **Global Journal of Pure and Applied Sciences**, 16(4), 501-506.
24. Oyedepo, O. O., &Akinniyi, J. A. (2013). The blood glucose-lowering effect of aqueous leaf extracts of *Vernoniaamygdalina*. **Nigerian Journal of Biochemistry and Molecular Biology**, 18, 32-35.
25. Richard, R. E., Chia, K. P., &Eze, E. N. (2015). Hypoglycemic effects of *Vernoniaamygdalina* on alloxan-induced diabetic rats. **Journal of Diabetic Complications**, 2(3), 141-150.
26. Tunde-Akintunde, T. Y., &Oyeniyi, S. K. (2011). Effect of *Vernoniaamygdalina* leaf extract on diabetes-induced hepatotoxicity. **African Journal of Biotechnology**, 10(58), 12432-12438.

27. Ukwé, C. V., & Akah, P. A. (2001). Hypoglycemic properties of *Vernonia amygdalina*. **West African Journal of Pharmacology and Drug Research**, 17(3), 32-37.
28. Uzoma, O., & Obiora, S. (2012). Comparative analysis of the antihyperglycemic potential of *Irvingia gabonensis*. **Journal of Biomedical Research**, 4(2), 89-94.
29. Wu, C., & Nieuwdorp, M. (2020). Gut microbiome and diabetes management. **Nature Reviews Gastroenterology & Hepatology**, 17, 487-496.

UNDER PEER REVIEW