GSC Biological and Pharmaceutical Sciences

eISSN: 2581-3250 CODEN (USA): GBPSC2

Cross Ref DOI: 10.30574/gscbps

Journal homepage: https://gsconlinepress.com/journals/gscbps/

(RESEARCH ARTICLE)

Check for updates

Evaluating plant-based extracts as alternative therapeutics for diabetes: experimental and clinical insights

Adaku Chukwudi-Mensah [1,*], Miriam Ebere Ogoke [2], Perpetua Obi Ndubuisi [3] and Olufemi Gabriel Abimbola [4]

[1] *Department of Home Economics, College of Applied Food Sciences and Tourism, Michael Okpara University of Agriculture Umudike, Nigeria.*

[2] *Department of Microbiology, College of Natural Sciences Michael Okpara University of Agriculture Umudike, Nigeria.*

[3] *Department of Plant Science and Biotechnology, College of Natural Sciences Michael Okpara University of Agriculture Umudike, Nigeria.*

[4] *Department of Nutrition and Health Sciences, Center of Biological Science and Health, Universidade Federal de Vicosa, Brazil.*

GSC Biological and Pharmaceutical Sciences, 2025, 31(03), 251-258

Publication history: Received on 10 May 2025; revised on 16 June 2025; accepted on 19 June 2025

Article DOI: https://doi.org/10.30574/gscbps.2025.31.3.0232

Abstract

Interest in natural; plant-based alternatives to pharmaceutical anti diabetic medications has surged due to their negative side effects. This study assessed the hypoglycemic potential of aqueous extracts from lemon grass; lemon rinds; scent leaf; moringa leaf; and bitter leaf in treating diabetes. Alloxan monohydrate was used to cause diabetes in 35 out of 40 rats that were fasted for the entire night. Rats were split up into control and treatment groups; and the treatment groups were given intragastric intubation every day for two weeks to receive 2 milliliters of either individual or mixed plant extracts. On days four; seven; ten; and fourteen; blood glucose levels were assessed. Five diabetic individuals who ingested the extracts were also involved in the trial; their blood glucose levels were measured 30; 60; 90; and 120 minutes after ingestion. Data were analyzed using SPSS version 21 with one-way ANOVA and Duncan's multiple range test at $p \leq 0.05$. Toxicological analysis revealed that lemon grass extract had the highest tannin (0.62±0.03) and oxalate (3.66±0.32) content; moringa extract recorded the highest phytate level (1.60±0.02); while bitter leaf contained the highest saponin concentration (2.00±0.01). In diabetic rats; untreated groups showed persistently high glucose levels; whereas treated groups exhibited significant reductions. Among human subjects; lemon grass extract led to the highest glucose readings post-consumption; though still lower than baseline. The combined extract demonstrated the most significant glucose-lowering effect in both rats and humans; suggesting synergistic benefits. These findings support the potential of these plant extracts as effective; natural alternatives in diabetes management; though further investigation into their long-term safety is warranted.

Keywords: Aqueous plant extract; Herbal therapeutics; Hyperglycemia; Diabetics mellitus

1. Introduction

Diabetes mellitus is a multifactorial metabolic disorder characterized by chronic hyperglycemia resulting from defects in insulin secretion, insulin action, or both. It is often associated with disturbances in the metabolism of carbohydrates, fats, and proteins, as well as oxidative stress, which can collectively contribute to long-term complications including cardiovascular disease, nephropathy, neuropathy, and retinopathy [1]. The global burden of diabetes continues to rise at an alarming rate. According to the World Health Organization [2], diabetes accounts for approximately 80% of deaths in developing countries. Data from the Centers for Disease Control and Prevention [3], further indicate that the number of individuals living with diabetes nearly tripled between 1990 and 2010.

* Corresponding author: Adaku Chukwudi-Mensah

Currently, an estimated 387 million people globally are afflicted with diabetes, with approximately 22 million of these residing in sub-Saharan Africa. Nigeria, as the most populous country in Africa, accounts for over 4 million cases about 20% of the diabetic population in the region (International Diabetes Federation) [4]. Of particular concern is the high limited healthcare resources in Nigeria. Consequently, many patients present with advanced complications, resulting in high morbidity and mortality rates. Although various synthetic hypoglycemic agents are available for diabetes management, their prolonged use often results in undesirable side effects and high treatment costs, limiting accessibility, especially in low-income settings (Consumer Report) [5]. As a result, there has been a growing interest in plant-based therapeutics within traditional and alternative medicine systems.

Plants and their bioactive phytochemicals offer promising anti-diabetic properties with reduced side effects and lower economic burdens [6]. Numerous studies suggest that the hypoglycemic effects of many medicinal plants are largely mediated by their antioxidant capacities [7], [8]. Among commonly consumed medicinal plants with reported anti-diabetic potential are *Cymbopogon citratus* (lemon grass), *Citrus limon* (lemon rind), *Ocimum gratissimum* (scent leaf), *Moringa oleifera* (moringa leaf), and *Vernonia amygdalina* (bitter leaf). These are readily available as dietary components and have been traditionally used across Africa and Asia for treating various ailments.

Moringa leaf (*Moringa oleifera)* member of the *Moringaceae* family, is indigenous to the sub-Himalayan tracts of India and has been naturalized in various tropical and subtropical regions. It is well-regarded for its nutritional value and wide pharmacological applications including antioxidant, anti-inflammatory, hepatoprotective, and anti-diabetic effects [9], [10], [11], [12], [13], [14], [15]. Lemon rinds (*Citrus limon* peels) are rich in phytochemicals such as β- and γ-sitosterol, flavonoids, polyethoxylated compounds, and ascorbic acid, contributing to their broad pharmacological effects including antimicrobial, anti-diabetic, and antioxidant activities [16].

Vernonia amygdalina, commonly known as bitter leaf, is a widely used medicinal plant in Nigeria. Bitter leaf and Moringa bitter taste attributed to anti-nutritional compounds such as alkaloids, tannins, and saponins [17]. The plant has demonstrated pharmacological relevance in the treatment of diabetes, gastrointestinal disorders, and parasitic infections, and is commonly employed in ethnomedicine for its tonic and anti-hypertensive properties [18], [19], [20], [21], [22].

Scent leaf (*Ocimum gratissimum)* a member of the *Lamiaceae* family, is used both for its nutritional and medicinal benefits. Traditionally, its leaves are applied in the management of fungal infections, convulsions, fever, and respiratory ailments. The essential oils of this plant have demonstrated antiseptic and anti-inflammatory activities [23], [24].

Lemon grass (*Cymbopogon citratus)* is widely cultivated in tropical regions and has been employed in folk medicine as a carminative, analgesic, antipyretic, and diuretic. Its essential oils and aqueous extracts exhibit anti-diabetic and anti-inflammatory effects [25] [26], [27], [28], [29].

Collectively, these plant species hold significant promise as low-cost, accessible alternatives for diabetes management. Therefore, this current study aims to evaluate the efficacy and safety of aqueous extracts from these plants through both experimental and clinical investigations.

2. Material and methods

2.1. Study Design

An experimental research design involving both animal and human subjects was adopted for this study. Diabetes mellitus was induced in thirty-five (35) out of forty (40) overnight-fasted Wistar albino rats via a single intraperitoneal injection of alloxan monohydrate (Sigma-Aldrich, USA) at a standard diabetogenic dose. Five (5) rats served as non-diabetic controls. The diabetic rats were randomly assigned into eight groups (A–H), with five animals per group. Group H (non-diabetic control) and Group G (diabetic control) received 2 ml of distilled water daily. Groups A–F received 2 ml of aqueous extracts from the following plants respectively: *Cymbopogon citratus* (lemon grass), *Citrus limon* rind (lemon peel), *Ocimum gratissimum* (scent leaf), *Vernonia amygdalina* (bitter leaf), *Moringa oleifera* (moringa leaf), and a combination of all five. Extracts were administered once daily via intra-gastric intubation for 14 consecutive days. Blood glucose levels were measured on days 5, 10, and 14 using tail vein blood and a glucometer (Accu-Chek, Roche Diagnostics). For the human study component, five (5) overnight-fasted diabetic patients were recruited from Life Essential Hospital, Umuahia, Nigeria. Each participant received one glass (approximately 200 ml) of the aqueous extract orally. Capillary blood glucose levels were measured at 30-, 60-, 90-, and 120-minutes post-ingestion using an Accu-Chek glucometer

2.2. Animal Ethics and Housing

All experimental procedures adhered to the ethical guidelines of the National Committee for Clinical Laboratory Standards [30]. Rats were housed in standard laboratory cages under controlled conditions (24 ± 2°C, 50% relative humidity, 12-hour light/dark cycle) and provided with standard rat chow and water ad libitum.

2.3. Preparation of Aqueous Plant Extracts

Fresh plant materials Lemon grass(*Cymbopogon citratus*), Lemon rinds (*Citrus limon* rind), Scent leaf (*Ocimum gratissimum)*,Bitter leaf (*Vernonia amygdalina)*, and Moringa leaf (*Moringa oleifera*) were purchased from Ubani Main Market, Umuahia, and authenticated at the Department of Plant Science and Biotechnology, Michael Okpara University of Agriculture, Umudike, Nigeria. Plant parts were thoroughly washed and air-dried at room temperature for three days. Each sample was boiled in distilled water for five minutes and filtered through muslin cloth to obtain the aqueous extract. For the combination formulation, equal volumes (2 ml each) of the individual extracts were mixed, and 2 ml of the blend was used as the standard therapeutic dose.

2.4. Sample Collection

In rats, blood samples for glucose monitoring were collected from the tail vein. At the end of the experiment, animals were fasted overnight, euthanized by decapitation, and blood samples collected into plain gel tubes and sodium citrate tubes (3.2%, 9:1 v/v). For human participants, capillary blood was collected via finger prick.

2.5. Phytochemical Screening

The phytochemicals and anti-nutritional factors such as saponin, alkaloids, flavonoids and tannins were determined. The Saponins were identified using the froth test. Alkaloids were tested with Mayer's and Wagner's reagents and chloroform extraction and acid re-extraction were also carried out. Flavonoids were detected by combining 5 ml of ethanol extract with 1 ml concentrated H_2SO_4 and 0.5 g magnesium and the presence of flavonoids was indicated by the appearance of a green to reddish coloration. Tannins contents of the sample were determined as tannic acid, as described by [31].

2.6. Statistical Analysis

Data were analyzed using SPSS version 21.0. One-way analysis of variance (ANOVA) was applied to determine significant differences in blood glucose levels and phytochemical content across groups. Mean values were separated using Duncan's Multiple Range Test. Statistical significance was considered at $p < 0.05$.

3. Results

Table 1 Toxicity level of the aqueous extracts

Samples	Tannin (mg/100g)	Phytate (mg/100g)	Oxalate (mg/100g)	Saponins (mg/100g)	Alkaloids (mg/100g)
LGAE	0.62^{a}±0.03	0.04^{e}±0.01	3.66^{a}±0.32	0.68^{d}±0.03	0.52^{b}±0.03
LRAE	0.01^{e}±0.01	0.04^{e}±0.01	0.06^{d}±0.02	0.45^{e}±0.03	0.53^{b}±0.03
BLAE	0.02^{d}±0.01	0.93^{b}±0.03	0.37^{c}±0.03	2.00^{a}±0.01	0.38^{c}±0.01
MLAE	0.05^{d}±0.01	1.60^{a}±0.02	0.87^{b}±0.03	0.47^{e}±0.03	1.08^{a}±0.02
SLAE	0.44^{b}±0.02	0.33^{d}±0.01	0.22^{c}±0.01	0.77^{c}±0.01	0.01^{d}±0.01
AMOFA	0.21^{c}±0.02	0.59^{c}±0.01	1.02^{b}±0.01	0.88^{b}±0.02	0.52^{b}±0.02

Values are means ± standard deviation of triplicate samples. $^{a-e}$ Means with similar superscripts in the same column are not significantly different (p>0.05). **Key**: LGAE: Lemon grass aqueous extract, LRAE; Lemon rind aqueous extract, BLAE; Bitter leaf aqueous extract, MLAE; Moringa leaf aqueous extract, SLAE; Scent leaf aqueous extract, AMOFA; Aqueous mixture of all.

Table 1 shows the toxicity of the aqueous extract. The tannin content was significantly highest (p<0.05) in LGAE (0.62±0.03 mg/100g), while LRAE recorded the lowest (0.01±0.01 mg/100g). No significant difference was observed between BLAE and MLAE. For phytates, MLAE had the highest content (1.60±0.02 mg/100g), while LGAE and LRAE showed the lowest values (0.04±0.01 mg/100g). Oxalate levels were highest in LGAE (3.66±0.32 mg/100g), and lowest

in LRAE (0.06±0.02 mg/100g). Saponins were significantly most abundant in BLAE (2.00±0.01 mg/100g), while LRAE and MLAE had the lowest and statistically similar values. Alkaloid content peaked in MLAE (1.08±0.02 mg/100g) and was lowest in SLAE (0.01±0.01 mg/100g).

In table 2 the control group (Group 2) showed persistently elevated glucose levels throughout the study period. In contrast, the group treated with the aqueous mixture of all extracts (Group 8) showed a significant and progressive decline in blood glucose, reaching 63.00±15.81 mg/dL on day 14. Groups treated with single plant extracts also showed significant reductions, though not as pronounced as Group 8.

Table 2 Blood glucose levels of the albino rats

Samples	Initial blood glucose (post alloxan induction)	Blood glucose at day 5	Blood glucose at day 10	Blood glucose at day 14
Group 1	73.80^{c}±14.82	80.20^{c}±5.07	78.20^{d}±10.99	77.60^{b}±12.10
Group 2	293.20^{b}±25.87	322.20^{a}±24.60	355.40^{a}±25.01	383.60^{a}±17.64
Group 3	305.20^{b}±30.29	222.20^{b}±38.80	143.60^{b}±32.25	76.00^{b}±17.26
Group 4	309.60^{b}±44.78	234.00^{b}±48.23	160.20^{b}±19.15	93.80^{b}±19.07
Group 5	313.80^{b}±29.52	213.20^{b}±23.66	131.40^{c}±29.05	89.80^{b}±20.72
Group 6	321.40^{b}±21.79	258.20^{b}±26.11	138.80^{b}±31.46	78.40^{b}±12.03
Group 7	303.80^{b}±29.79	229.00^{b}±36.22	151.20^{b}±22.30	90.00^{b}±11.25
Group 8	349.80^{a}±38.41	220.20^{b}±40.02	103.80^{c}±9.18	63.00^{c}±15.81

Values are means ± standard deviation of five animals per group. $^{a-d}$ Means with different superscripts in the same column are significantly different ($p<0.05$). Key: Group 1; Normal control (Normal rats receiving 2ml distilled water) ,Group 2; Diabetic control (Diabetic rats receiving 2ml distilled water), Group 3; Diabetic rats receiving 2ml aqueous extract from bitter leaf, Group 4; Diabetic rats receiving 2ml aqueous extract from scent leaf, Group 5; Diabetic rats receiving 2ml aqueous extract from Moringa leaf, Group 6; Diabetic rats receiving 2ml aqueous extract from lemongrass, Group 7; Diabetic rats receiving 2ml aqueous extract from lemon rind, Group 8; Diabetic rats receiving 2ml aqueous mixture of extracts from lemon rind, bitter leaf, moringa leaf, scent leaf and lemongrass

Table 3 shows the effect of Aqueous Extracts on Blood Glucose Levels in Diabetic Humans. The aqueous mixture (AMOFA) consistently exhibited the highest glucose-lowering effect across all time points, significantly reducing blood glucose from 219.20±36.01 mg/dL to 80.40±10.04 mg/dL after 120 minutes. LGAE showed the least glucose-lowering potential, with non-significant changes in values across time points

Table 3 Blood glucose levels of the diabetics

Samples	Initial blood glucose level	After 30 minutes	After 60 minutes	After 90 minutes	After 120 minutes
LGAE	214.60^{a}±30.00	216.20^{a}±31.22	196.00^{a}±38.47	174.60^{a}±35.63	141.60^{a}±22.20
LRAE	175.00^{a}±22.72	166.20^{b}±15.24	142.20^{b}±8.79	118.60^{b}±7.86	96.60^{bc}±7.33
BLAE	194.80^{a}±1 7.48	175.80^{ab}±18.12	139.40^{b}±12.78	108.80^{b}±7.89	86.60^{c}±13.13
MLAE	196.60^{a}±44.00	176.60^{ab}±49.33	151.00^{b}±45.32	123.60^{b}±33.31	95.00^{bc}±19.42
SLAE	183.80^{a}±23.26	163.40^{b}±19.31	148.00^{b}±18.12	132.20^{b}±20.95	109.80^{b}±19.64
AMOFA	219.20^{a}±36.01	175.60^{ab}±27.51	132.80^{b}±22.80	104.40^{b}±10.69	80.40^{c}±10.04

Values are means ± standard deviation of triplicate samples. $^{a-b}$ Means with similar superscripts in the same column are not significantly different ($p>0.05$). **Key**: LGAE: Lemon grass aqueous extract, LRAE; Lemon rind aqueous extract, BLAE; Bitter leaf aqueous extract, MLAE; Moringa leaf aqueous extract, SLAE ; Scent leaf aqueous extract, AMOFA; Aqueous mixture of all

4. Discussion

4.1. Toxicological Assessment of Aqueous Extracts

Although aqueous plant extracts are widely utilized in African traditional medicine for their healing properties but they also contain bioactive compounds that may exert toxic effects when consumed in excess. In this present study, *Cymbopogon citratus* (lemon grass) aqueous extract exhibited the highest tannin content (0.62 ± 0.03 mg/g). Tannins are known for their astringent properties and traditional use in the treatment of wounds, diarrhea, and dysentery, reflecting their antimicrobial potential [32]. Furthermore, tannins have been reported to serve as antidotes to various toxins [33] and may improve blood lipid profiles [34] (Laura, 2011). However, prolonged consumption of high-tannin diets has been linked to adverse effects, including increased risk of cancers of the nasal and pharyngeal cavities, as well as damage to liver, kidney, and cardiac tissues. These findings emphasize the importance of dosing in herbal formulations. The *Moringa oleifera* leaf extract showed the highest phytate concentration (1.60 ± 0.02 mg/g), which was lower than the 2.57% reported by [35]. But in agreement with the levels reported by [36]. Phytates, while traditionally considered anti-nutrients due to their mineral-chelating capacity, have also demonstrated antioxidant properties and possible protective roles in degenerative diseases. This supports the traditional use of *Moringa* as both a food and a medicinal plant in African households. Oxalate content was highest in *C. citratus* (3.66 ± 0.32 mg/g), although still within levels considered nutritionally acceptable. Oxalates in excessive amounts may interfere with calcium absorption or contribute to renal calculi formation, yet moderate levels, as observed here, may not pose significant risks and may even support mineral bioavailability [37]. The highest saponin content was observed in *Vernonia amygdalina* (bitter leaf) extract (2.00 ± 0.01 mg/g). This is consistent with prior studies [38], which reported saponin levels of approximately 2.15% in bitter leaf. Saponins are known to possess hypoglycemic, cholesterol-lowering, and immunomodulatory properties, which further support the ethnomedical use of *V. amygdalina* in managing metabolic disorders.

4.2. Anti-Diabetic Effects in Experimental Models

Diabetes mellitus remains a pressing public health challenge in Africa, where many rely on plant-based remedies for disease management. The induction of diabetes using alloxan in experimental rats resulted in significant hyperglycemia, confirming the cytotoxic effect of alloxan on pancreatic β-cells as documented by [39]. The observed destruction of β-cells is attributed to the oxidative stress caused by alloxan and its metabolite, dialuric acid, which initiate a redox cycle and superoxide radical formation leading to lipid peroxidation and cell necrosis [40]. Treatment with aqueous extracts of *M. oleifera* (moringa leaf) *C. citratus* (Lemon grass) *V. amygdalina* (bitter leaf) *Citrus limon (*lemon rind), and *Ocimum gratissimum* (scent leaf) led to a significant reduction in fasting blood glucose levels in diabetic rats. This supports the folkloric use of these plants across various African communities in managing symptoms of diabetes and aligns with previous findings by [41], [42] and [43]. The hypoglycemic action may be due to inhibition of intestinal glucose uptake, improvement in insulin sensitivity, or regeneration of pancreatic β-cells.

4.3. Glycemic Response in Human Subjects

In human subjects, individuals treated with *C. citratus* (lemon grass) aqueous extract recorded the highest blood glucose levels at 60, 90, and 120 minutes post-treatment. Although a downward trend in glucose was observed, the effect was less potent compared to other single-extract groups. In contrast, individuals receiving the combination of all five plant extracts exhibited the lowest blood glucose levels across all time points, suggesting a synergistic interaction among the phytochemical constituents. This mirrors the traditional African healing approach where polyherbal formulations are favored over single-plant remedies to enhance efficacy and balance toxicity. The combination treatment likely benefits from the complementary action of different bioactive compounds, including flavonoids, polyphenols, alkaloids, and saponins each contributing to glucose modulation through diverse pathways [44], [45].

4.4. Implications for Traditional and Integrative Medicine

These findings validate the ethnomedical use of selected plant extracts in the management of diabetes mellitus. While individual extracts demonstrated appreciable hypoglycemic activity, the superior efficacy of the combination therapy reflects the wisdom embedded in African traditional medicine a trend supported by systematic reviews demonstrating enhanced glycemic control in human subjects using polyherbal formulations (Shing et al., 2021). However, the presence of anti-nutritional factors such as tannins, phytates, and oxalates underscores the need for caution in dosage and long-term use. Further research should focus on isolating active constituents, evaluating chronic toxicity, and conducting randomized clinical trials to facilitate the integration of these botanicals into formal health systems. Such steps would enhance the scientific credibility of African traditional medicine while preserving its rich heritage [45], [46].

5. Conclusion

This study provides scientific validation for the traditional use of selected plant extracts, *Moringa oleifera*, *Cymbopogon citratus*, *Vernonia amygdalina*, *Ocimum gratissimum*, and *Citrus limon* in the management of diabetes mellitus. The observed hypoglycemic effects in both experimental animals and human subjects affirm the therapeutic relevance of these botanicals within African ethno medicine. The combination of all five extracts exhibited the most pronounced glucose-lowering activity, reflecting the synergistic benefits often harnessed in traditional poly herbal formulations. While the phytochemicals responsible for these effects such as tannins, saponins, oxalates, and phytates confer potential therapeutic value, they also underscore the importance of appropriate dosing and safety evaluation. The findings support the inclusion of indigenous plants in complementary healthcare strategies, especially in resource-limited settings where access to conventional drugs may be restricted. Future investigations should explore the molecular mechanisms underlying these hypoglycemic effects, assess long-term toxicity profiles, and evaluate the efficacy of these extracts through controlled clinical trials. In doing so, traditional knowledge can be harmonized with scientific evidence to promote culturally congruent, accessible, and effective treatment modalities for chronic diseases like diabetes.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

Statement of ethical approval

All experimental procedures adhered to the ethical guidelines of the National Committee for Clinical Laboratory Standards.

References

[1] Onaolapo, O. J., Olugbenga, O. O., and Adeniran, S. O. (2011). Comparative antidiabetic study of aqueous extract of Moringa oleifera leaves and metformin in streptozotocin-induced diabetic rats. International Journal of Applied Research in Natural Products, 4(3), 1–6.

[2] World Health Organization. (2006). Definition and diagnosis of diabetes mellitus and intermediatehttps://www.who.int/diabetes/publications/diagnosis_diabetes2006/en/

[3] Centers for Disease Control and Prevention. (2012). National diabetes fact sheet. https://www.cdc.gov/diabetes/pubs/factsheet.htm

[4] International Diabetes Federation. (2014). IDF Diabetes Atlas (6th ed.). https://www.idf.org/

[5] Consumer Reports. (2012). Herbal supplements: Benefits and risks. Consumer Reports Magazine, 77(10), 14–19.

[6] Bansal, M. P., Bansal, M. R., et al. (1980). Alloxan-induced diabetes and pancreatic damage. Diabetologia, 18, 97–101.

[7] Mollace, V., Sacco, I., Janda, E., et al. (2011). Protective effects of Moringa oleifera leaf extract on neurodegeneration. Molecules, 16(9), 8171–8180.

[8] Yin, J., Zhang, H., and Ye, J. (2011). Traditional Chinese medicine in treatment of metabolic syndrome. Endocrine, Metabolic and Immune Disorders - Drug Targets, 8(2), 99–111

[9] Khawaja, T. M., Khan, M. A., and Hadi, S. M. (2010). Mechanism of alloxan-induced diabetes: Role of reactive oxygen species. Diabetes Research and Clinical Practice, 88(3), 298–302.

[10] Hamza, A. A. (2010). Ameliorative effects of Moringa oleifera Lam. seed extract on liver fibrosis in rats. Food and Chemical Toxicology, 48(1), 345–355.

[11] Singh, D., Arya, P. V., and Kumar, S. (2012). Evaluation of antidiabetic activity of ethanolic extract of Ocimum gratissimum Linn. in streptozotocin-induced diabetic rats. Asian Journal of Pharmaceutical and Clinical Research, 5(2), 45–47.

[12] Paliwal, R., Sharma, V., and Pracheta. (2011). A review on horse gram: Macro and micronutrient profile. International Journal of Pharmaceutical Sciences and Research, 2(3), 567–574.

[13] Sharma, R., Sharma, V., and Paliwal, R. (2012). Evaluation of antidiabetic and antioxidant effects of Ocimum sanctum Linn. in experimental diabetes. Journal of Pharmaceutical Research, 5(7), 3631–3634.

[14] Lai, P. K., Roy, J., Gopalan, R., and Wong, S. F. (2010). Herbal remedies and functional foods used in the management of diabetes mellitus. African Journal of Biotechnology, 9(44), 7490–7494.

[15] Huang, C., Wang, Y., Li, X., et al. (2012). Clinical efficacy of traditional Chinese medicine combined with Western medicine in the treatment of diabetes mellitus. Journal of Traditional Chinese Medicine, 32(3), 381–384.

[16] Amit, S. K., Uddin, M. M., Rahman, R., et al. (2011). A review on mechanisms and pathophysiology of type 2 diabetes mellitus. Journal of Applied Pharmaceutical Science, 1(6), 1–6.

[17] Ologunde, M. O., and Adeleye, T. I. (1992). The effect of Ocimum gratissimum on blood glucose level in alloxan diabetic rabbits. Nig. J. Biochem., 7, 85–89.

[18] Jisaka, M., Ohigashi, H., Takagaki, T., et al. (1993). Steroid glycosides from Vernonia amygdalina, a possible chemo-preventive agent against tumor promotion. Agricultural and Biological Chemistry, 57(2), 315–320.

[19] Hamowia, A. M., and Safran, M. A. (1994). The antifertility effect of Moringa oleifera in adult male rats. Journal of Ethnopharmacology, 43(2), 117–121.

[20] Regassa, A. (2000). The use of herbal preparations for the treatment of animal diseases in rural Ethiopia. Veterinary Journal, 157(1), 1–10.

[21] Kambizi, L., and Afolayan, A. J. (2001). An ethnobotanical study of plants used for the treatment of sexually transmitted diseases (njovhera) in Guruve District, Zimbabwe. Journal of Ethnopharmacology, 77(1), 5–9.

[22] Amira, C. O., and Okubadejo, N. U. (2007). Frequency and pattern of complementary and alternative medicine use in patients with epilepsy attending a tertiary health facility in Lagos, Nigeria. Epilepsy and Behavior, 10(4), 576–580.

[23] Idris, M. A., Abubakar, M. S., and Ahmed, A. (2011). Phytochemical screening and antimicrobial activity of leaf extracts of Vernonia amygdalina Del. Journal of Medicinal Plants Research, 5(30), 7016–7020.

[24] Edeoga, H. O., and Eriata, D. O. (2001). Alkaloid, tannin and saponin contents of some Nigerian medicinal plants. Journal of Medicinal and Aromatic Plant Sciences, 23(3), 344–349.

[25] Francisco, C. A., da Silva, M. I. G., Ferreira, P. B., et al. (2011). Evaluation of antioxidant and antidiabetic potential of Ocimum gratissimum L. leaves extract in streptozotocin-induced diabetic rats. PharmacologyOnline, 1, 33–44.

[26] Figueirinha, A., Paranhos, A., Pérez-Alonso, J. J., Santos-Buelga, C., and Batista, M. T. (2008). Cymbopogon citratus leaves: Characterization of flavonoids by HPLC–PDA–ESI/MS/MS and an approach to their potential as a source of bioactive polyphenols. Food Chemistry, 110(3), 718–728.

[27] Viana, G. S. B., Medeiros, A. C. D., Lacerda, A. M. R., et al. (2000). Hypoglycemic and anti-lipemic effects of Vernonia amygdalina extract in alloxan-induced diabetic rats. Journal of Ethnopharmacology, 72(1–2), 113–117.

[28] Negrelle, R. R. B., and Gomes, E. C. (2007). Ocimum gratissimum L.: Essential oil composition and biological properties: A review. Brazilian Archives of Biology and Technology, 50(1), 161–168.

[29] National Committee for Clinical Laboratory Standards (NCCLS), Performance standards for antimicrobial disk susceptibility tests; Approved standard. 7th ed. NCCLS document M2-A7. Wayne, PA: National Committee for Clinical Laboratory Standards, 2000.

[30] Ndubuisi, P. O., Eze, C. E., and Amadi, C. O. (2022). Comparative study of proximate, mineral and anti-nutrient composition of African yam bean (Sphenostylis stenocarpa Hochst Ex. A. Rich.) accessions. Agricultural Science Digest. https://doi.org/10.18805/ag.DF-483

[31] Dharmananda, S. (2003). Gallnuts and the uses of tannins in Chinese medicine. Institute for Traditional Medicine.

[32] Norton, R. A. (2000). Tannins in animal nutrition. Feedstuffs, 72(36), 12–14.

[33] Laura, S. (2011). Tannins in nutrition and health. Journal of Medicinal Food, 14(5), 456–462.

[34] Ogbe, A. O., and Affiku, J. P. (2012). Proximate study, mineral and anti-nutrient composition of Moringa oleifera leaves harvested from Lafia, Nigeria: Potential benefits in poultry nutrition and health. Journal of Microbiology, Biotechnology and Food Sciences, 1(3), 296–308.

[35] Soetan, K. O., and Aiyelaagbe, O. O. (2006). The need for bioactivity-safety evaluation and conservation of medicinal plants. Journal of Medicinal Plants Research, 5(5), 1–10.

[36] Akindahunsi, A. A., and Salawu, S. O. (2005). Phytochemical screening and nutrient-antinutrient composition of selected tropical green leafy vegetables. African Journal of Biotechnology, 4(6), 497–501.

[37] Atangwho, I. J., Ebong, P. E., Eyong, E. U., Williams, I. O., Eteng, M. U., and Egbung, G. E. (2009). Comparative chemical composition of leaves of some antidiabetic medicinal plants: Azadirachta indica, Vernonia amygdalina and Gongronema latifolium. African Journal of Biotechnology, 8(18), 1648–1651.

[38] Nimenibo, U. S., Olotu, F. O., and Itam, E. H. (2003). Alloxan-induced diabetes in Wistar rats: A model for studying the effect of antidiabetic agents. Nigerian Journal of Physiological Sciences, 18(2), 23–29.

[39] Grankvist, K., Marklund, S. L., and Taljedal, I. B. (1979). Superoxide dismutase is essential for the protection of insulin-producing cells against the toxic effect of alloxan. Diabetes, 28(12), 113–117.

[40] Aderibigbe, A. O., Emudianughe, T. S., and Lawal, B. A. (1999). Antihyperglycemic effect of Mangifera indica in rat. Phytotherapy Research, 13(6), 504–507.

[41] Akah, P. A., and Okafor, C. L. (2006). Blood sugar lowering effect of Vernonia amygdalina Del. in an experimental rabbit model. Phytotherapy Research, 20, 748–752.

[42] Abbas, G., Aslam, M., Jabeen, A., et al. (2018). Anti-diabetic potential of medicinal plants and their active constituents: A review. Biomedicine and Pharmacotherapy, 107, 1240–1249.

[43] Etim, O. E., Akpan, E. J., Uboh, F. E., and Offor, U. S. (2020). Efficacy of composite extract from leaves and fruits of medicinal plants used in traditional diabetic therapy against oxidative stress in alloxan-induced diabetic rats. Journal of Ethnopharmacology, 249, 112381.

[44] Shrime, M. G., Bauer, S., McDonald, A. C., and Desai, P. (2011). Polyherbal formulations for the treatment of type 2 diabetes mellitus: A systematic review and meta-analysis. Journal of Ethnopharmacology, 158, 738–747.

[45] Eriocitrin Study Group. (2023). Eriomin (eriocitrin): randomized, double-blind, placebo-controlled crossover trial in individuals with prediabetes. Nutrients, 15(4), 678.