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Proximate Composition, Phytochemical Composition, and Hypolipidemic Activities of Methanolic Extracts of Selected Medicinal Plants Used in Traditional Medicine in Southern Nigeria

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Abstract

Background This study examined the proximate composition, phytochemical profile, and hypolipidemic effects of methanolic extracts from four medicinal plants used in Southern Nigeria: Vernonia amygdalina, Ocimum gratissimum, Moringa oleifera, and Gongronema latifolium. The goal was to assess their nutritional value and potential for lipid regulation and cardiovascular health.

Methods Proximate analysis of moisture, protein, fat, ash, fiber, and carbohydrates was performed using Association of Official Analytical Chemists protocols. Qualitative tests identified the presence of flavonoids, saponins, alkaloids, tannins, and phenols. Thirty male Wistar rats (150–180 g) were divided into five groups, fed a high-fat diet to induce hyperlipidemia, and treated orally with plant extracts (200 mg/kg) for 21 days. Serum lipid levels (total cholesterol, triglycerides, low-density lipoprotein, and high-density lipoprotein) and liver enzymes (ALT and AST) were measured.

Results Moringa oleifera had the highest protein (21.5%), fat (8.0%), and ash (5.8%). V. amygdalina contained the most fibre (15.0%), while G. latifolium had the highest carbohydrate content (56.3%). All extracts contained key phytochemicals. Treatment significantly ($p < 0.05$) reduced TC, TG, and LDL and increased HDL. M. oleifera showed the strongest lipid-lowering effect. Extracts also lowered ALT and AST levels. O. gratissimum and V. amygdalina offered the greatest hepatoprotective activity.

Conclusion These plants provide nutritional and therapeutic benefits. They improve lipid balance and protect liver function without toxicity. Their strong potential as safe, natural agents for managing hyperlipidemia and cardiovascular risk warrants further clinical trials.

Keywords Hepatoprotective, Hypolipidemic, Lipid profile, Medicinal plants, Phytochemical, Proximate

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1 Introduction

Medicinal plants play a crucial role in both traditional and modern healthcare systems, offering significant benefits. Around 80% of rural populations depend on these plants as their primary source of healthcare.[1-3] Historically, plants have been used globally for treating various ailments, with Africa maintaining strong traditional practices. Despite advancements in synthetic drugs, over 25% of modern pharmaceuticals are plant-derived. However, traditional medicinal plants remain under-researched, especially in developing regions where affordability limits access to synthetic medications.[3, 4]

The use of medicinal plants in traditional medicine has a long history, particularly in tropical regions like Southern Nigeria, where plants are integral to the management of various ailments.[3,5] Among the diverse therapeutic activities attributed to these plants, the regulation of lipid metabolism and the management of hyperlipidemia are of significant interest.[6] Medicinal plants have been identified as natural sources of bioactive compounds with potential hypolipidemic effects, while raising HDL (high-density lipoproteins) cholesterol.[7] Some plants also offer hepatoprotective benefits, safeguarding liver function, which is crucial for lipid metabolism.[8]

Moringa oleifera (M. oleifera) is one of the most well-known plants, widely recognized for its broad range of therapeutic effects. Studies have reported that M. oleifera leaf extracts exhibit hypolipidemic properties by reducing serum total cholesterol (TC), triglycerides (TG), and low-density lipoprotein (LDL), while elevating HDL levels.[9] Its bioactive compounds, including flavonoids, polyphenols, and alkaloids, are believed to contribute to these lipid-lowering effects.[10]

Vernonia amygdalina (V. amygdalina) is another plant that has garnered attention for its potential in managing hyperlipidemia. Commonly known as bitter leaf, it contains numerous bioactive compounds such as flavonoids, saponins, and alkaloids.[11] Research has shown that V. amygdalina can reduce serum lipid levels and improve the liver's ability to metabolize lipids.[12] Its antioxidant properties may also protect against oxidative stress, which is a key factor in the development of hyperlipidemia.[13, 14]

Ocimum gratissimum (O. gratissimum), commonly known as scent leaf, has also been investigated for its therapeutic potential. Studies have demonstrated that its leaves contain bioactive compounds such as flavonoids and tannins, which have been shown to lower cholesterol levels and provide anti-inflammatory and antioxidant effects.[15] These properties make O. gratissimum an effective plant for managing conditions associated with lipid imbalance and oxidative stress.[16]

Gongronema latifolium (G. latifolium) is another medicinal plant used in traditional medicine for the management of various ailments, including those related to hyperlipidemia. Research has indicated that the leaf extracts of G. latifolium possess hypolipidemic properties, as they can reduce serum lipid levels, including total cholesterol and triglycerides.[17] The plant's antioxidant activities are thought to be responsible for its effects on lipid metabolism.[18]

The proximate composition of medicinal plants provides insight into their nutritional value, which is critical in understanding their dual roles as food and medicine. For instance, many plants used in traditional medicine are rich in essential macronutrients, such as carbohydrates, proteins, and lipids, as well as dietary fibre, which are known to influence lipid metabolism. Additionally, the mineral content (ash) in these plants often contributes to their bioactivities by acting as cofactors for enzymatic processes.

Phytochemicals such as flavonoids, tannins, saponins, and alkaloids are integral to these hypolipidemic effects. They function by modulating cholesterol absorption, promoting lipolysis, and regulating lipid transport across biological membranes.

Hyperlipidemia is defined by elevated levels of TC, TG, and LDL, all of which are key contributors to the development of cardiovascular diseases and metabolic disorders such as atherosclerosis and diabetes. Conversely, HDL, often termed "good cholesterol," plays a protective role by facilitating reverse cholesterol transport. Hence, investigating the hypolipidemic potential of these medicinal plants offers a scientific basis for their traditional usage and supports the development of plant-based therapies for lipid disorders.[19] However, despite these reported benefits, there is limited empirical evidence on the comparative nutritional and hypolipidemic effects of these plants, particularly within the Southern Nigerian context. Given the increasing prevalence of hyperlipidemia and its associated risks, this study aims to investigate the proximate composition, phytochemical constituents, and hypolipidemic activities of four medicinal plants commonly used in Southern Nigeria. By evaluating their nutritional and lipid-lowering properties, this study seeks to provide scientific validation for their traditional use and explore their potential as natural alternatives in lipid metabolism management.

2 Methods

Plant Collection and Extraction

The leaves of V. amygdalina, O. gratissimum, M. oleifera, and G. latifolium were collected from their natural habitats in Southern Nigeria and identified by a botanist. The collected leaves were thoroughly washed under running water to remove dirt and debris. After washing,

the leaves were air-dried in the shade at room temperature for 5–7 days to reduce moisture content. Once dried, the leaves were finely ground using a mechanical grinder into a powder form. About 50 g of the powdered leaf material was weighed and subjected to cold maceration in 300 mL of methanol (90%) for 72 hours. The mixture was stirred periodically to ensure thorough contact between the solvent and plant material. After the maceration period, the mixture was filtered through Whatman No. 1 filter paper to separate the solvent from the solid plant residue. The resulting crude extract was then concentrated under reduced pressure using a rotary evaporator at 40°C to remove the methanol. The concentrated extracts were subsequently dried and stored in airtight containers at 4°C until further analysis.

The extraction process was performed in triplicate for each plant to ensure reproducibility and reliability of the results. The extracts were then subjected to various qualitative and quantitative analyses to determine their phytochemical composition and bioactivity, as described in the study by Shaikh and Patil[20] and other similar methods utilized for plant extract preparation in pharmacological research.[21]

Proximate Analysis

The proximate composition of the methanolic extracts of the leaves of V. amygdalina, O. gratissimum, M. oleifera, and G. latifolium was evaluated using standard analytical techniques to determine the moisture content, ash content, crude protein, crude fat, crude fibre, and carbohydrate content. The methods used for the proximate analysis were adapted from the procedures described by Abdu and Ashiru Garba[22] and Association of Official Analytical Chemists (AOAC).[23]

- **Moisture Content**

The moisture content was determined by drying 5 g of each plant extract at 105°C in an oven until a constant weight was achieved. The moisture content was calculated as the percentage loss in weight before and after drying using the formula:

$$Moisture\ Content = \left(\frac{\text{Initial Weight} - \text{Final Weight}}{\text{Initial Weight}}\right) \times 100$$

- **Ash Content**

The ash content, representing the total inorganic matter (minerals) in the plant extract, was determined by incinerating 5 g of the dried sample in a muffle furnace at 550°C until a white, ashy residue remained. The percentage of ash was calculated as:

$$Ash\ Content = \left(\frac{\text{Weight of ash}}{\text{Initial Weight}}\right) \times 100$$

- **Crude Protein**

The crude protein content was determined by the Kjeldahl method, which involves digesting the plant sample in concentrated sulfuric acid and determining the nitrogen content. The protein content was calculated using the formula:

$$Crude\ Protein = Nitrogen\ Content \times 6.25$$

Where 6.25 is the conversion factor from nitrogen content to protein.

- **Crude Fat**

The crude fat content was determined using the Soxhlet extraction method. Approximately 5 g of the dried plant extract was placed in a thimble and subjected to extraction with petroleum ether for 6 hours in a Soxhlet apparatus. The fat content was calculated by:

$$Crude\ Fat = \left(\frac{Weight\ of\ Extracted\ Fat}{Initial\ Weight\ of\ Sample}\right) \times 100$$

- **Crude Fibre**

The crude fibre content was determined by boiling 2 g of the dried plant sample in a solution of 1.25% sodium hydroxide (NaOH) and 1.25% sulphuric acid (H_2SO_4). After washing and drying, the residue was weighed and the fibre content calculated as:

$$\text{Crude fibre} = \left(\frac{\text{Weight of Residue}}{\text{Initial Weight of Sample}}\right) \times 100$$

- **Carbohydrate Content**

The carbohydrate content was determined by difference. Since the other proximate components (moisture, ash, protein, fat, and fibre) were measured, the carbohydrate content was calculated as:

$$Carbohydrate\ Content = 100 - (Moisture + Ash + Crude\ Protein + Crude\ Fat + Crude\ fibre)$$

Experimental Animals

The experimental animals used in this study were male adult Wistar rats (Rattus norvegicus) with an average weight range of 150-200 g. These animals were sourced from the animal house of the University of Port Harcourt and were allowed to acclimatize to the laboratory environment for a period of 7 days before the commencement of the study. This acclimatization period helped the animals adapt to the laboratory conditions, including the temperature, light/dark cycle, and handling procedures. The rats were housed in clean, well-ventilated, and spacious plastic cages. The animals were given access to a standard rodent diet, consisting of commercial rat chow and tap water, both of which

were provided ad libitum throughout the experiment. The environmental conditions were controlled, with the room temperature maintained at 25 ± 2°C and a 12-hour light/dark cycle, to mimic natural living conditions and minimize stress factors that could affect the experimental outcomes.

Ethical considerations were of utmost importance, and all procedures involving the animals were conducted in accordance with the ethical guidelines for animal care and use. The rats were closely monitored for signs of distress, illness, or adverse effects during the course of the study.

The adult male Wistar rats (150–200 g) were randomly divided into six groups (n = 6 per group):

Group 1: Normal Control fed a standard diet.
Group 2: Negative Control fed a high-fat diet.
Group 3: Fed a high-fat diet + 200 mg/kg methanolic extract of V. amygdalina.
Group 4: Fed a high-fat diet + 200 mg/kg methanolic extract of O. gratissimum.
Group 5: Fed a high-fat diet + 200 mg/kg methanolic extract of M. oleifera.
Group 6: Fed a high-fat diet + 200 mg/kg methanolic extract of G. latifolium.

The dosage of 200 mg/kg body weight for each plant extract was selected based on prior pharmacological studies that reported hypolipidemic activity at this concentration without observed toxicity.[9, 12]

Biochemical Analysis

Biochemical analysis was carried out to evaluate the hypolipidemic effects of the methanolic leaf extracts of the selected medicinal plants on the lipid profile of the experimental animals. The primary biochemical parameters assessed in this study included total cholesterol, triglycerides, low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), and serum liver enzymes such as alanine transaminase (ALT) and aspartate transaminase (AST). These parameters were chosen as they are key indicators of lipid metabolism and liver function, and are frequently used to assess the impact of herbal interventions on lipid homeostasis.

After 28 days, the rats were fasted overnight to minimize the influence of recent food intake on the biochemical analysis. Blood samples were then collected from the animals via cardiac puncture under mild anesthesia using a sterile syringe. The collected blood was transferred into non-heparinized tubes, allowed to clot at room temperature, and subsequently centrifuged at 3,000 rpm for 10 minutes to separate the serum. The serum was carefully aspirated and stored at -20°C for a maximum duration of 14 days prior to biochemical analysis to prevent enzymatic degradation. Before the assays were conducted, all serum samples were inspected visually for signs of hemolysis. Hemolyzed samples were excluded from the analysis to avoid inaccurate readings, especially for liver enzymes and lipid profile parameters.

- **Total Cholesterol and Triglycerides**: The levels of total cholesterol and triglycerides in the serum were measured using enzymatic colorimetric methods based on the Trinder reaction, in which the absorbance of the resulting quinoneimine dye is measured at 500 nm using Randox enzyme-based kits (Randox Laboratories, UK).

- **LDL-C and HDL-C:** The levels of LDL-C and HDL-C were determined using a precipitation method. In this method, LDL-C and HDL-C were separated by adding specific reagents that precipitate non-HDL lipoproteins, allowing the measurement of HDL-C. The remaining supernatant, containing LDL-C, was further processed to quantify the LDL-C concentration. Both lipoproteins were quantified using commercial reagent kits designed for lipid profiling (Randox Laboratories, UK).

- **Liver Enzymes (ALT and AST):** Liver enzyme activities (ALT and AST) were determined using Randox diagnostic kits (Randox Laboratories, UK) following the manufacturer's instructions. The assays employed kinetic enzymatic colorimetric methods, with enzyme activity measured by the rate of NADH oxidation at 340 nm.

3 Results

Proximate Composition

The nutritional profiles of the selected medicinal plants exhibit notable variations in moisture, ash, protein, fat, fibre, and carbohydrate contents. Table 1 summarises the proximate composition of V. amygdalina, O. gratissimum, M. oleifera, and G. latifolium. Moisture content was relatively consistent across the plants, with V. amygdalina showing the highest value. Protein content was particularly abundant in M. oleifera, while G. latifolium exhibited the highest carbohydrate content, highlighting its potential as an energy source. Fibre content was highest in V. amygdalina, which may enhance its dietary benefits.

Phytochemical Composition

Qualitative Phytochemical Composition

The phytochemical screening of the selected medicinal plants was conducted to identify their most active medicinal constituents. The qualitative analysis revealed

Table 1 Proximate composition of selected medicinal plants

Component	V. amygdalina	O. gratissimum	M. oleifera	G. latifolium
Moisture	9.0	8.5	7.8	8.0
Ash	5.0	4.5	5.8	5.2
Protein	15.0	14.5	21.5	13.0
Fat	6.5	7.2	8.0	6.0
Fibre	15.0	10.0	12.0	11.5
Carbohydrate	49.5	55.3	44.9	56.3

the presence of alkaloids, flavonoids, saponins, tannins, and phenolic compounds, highlighting their potential therapeutic significance.

Table 2 summarises the phytochemical composition of V. amygdalina, O. gratissimum, M. oleifera, and G. latifolium. Flavonoids were notably abundant in O. gratissimum, with high levels also observed in V. amygdalina, M. oleifera, and G. latifolium. Saponins were present at high levels in V. amygdalina, O. gratissimum, and M. oleifera, while moderate levels were found in G. latifolium. Alkaloids were highly abundant in M. oleifera and G. latifolium, with moderate levels in V. amygdalina and O. gratissimum. Tannins were most concentrated in V. amygdalina and O. gratissimum, with moderate amounts in M. oleifera and G. latifolium. Phenolic compounds were abundant in M. oleifera and G. latifolium, while moderate levels were observed in V. amygdalina and O. gratissimum**.**

Quantitative Phytochemical Composition

The quantitative phytochemical analysis of the selected medicinal plants highlights significant variations in the concentrations of bioactive compounds, as summarised in Table 3.

Flavonoids were most abundant in O. gratissimum, with substantial levels also observed in G. latifolium and V. amygdalina. Saponins were highest in G. latifolium, followed by O. gratissimum and Moringa oleifera. Alkaloids were particularly notable in M. oleifera, with moderate levels recorded in the other plants. Tannins and phenols exhibited moderate distributions across the plants, with O. gratissimum and G. latifolium showing higher levels compared to V. amygdalina and M. oleifera.

Hypolipidemic Activity

The hypolipidemic activity of methanolic extracts from the selected medicinal plants was assessed based on their impact on serum lipid profiles and liver enzyme activities in experimental animals. The extracts demonstrated significant potential in improving lipid metabolism and protecting liver function, as detailed below.

Serum Lipid Profiles

The results in Table 4 show that all plant extracts significantly ($p < 0.05$) reduced levels of TC, TG, and LDL while increasing HDL levels in the treated groups compared to the hyperlipidemic negative control. In the negative control group, TC levels were elevated at 180.0 ± 4.2 mg/dL, whereas treatment with M. oleifera resulted in the most notable reduction to 100.0 ± 3.0 mg/dL. This was closely followed by O. gratissimum (105.0 ± 2.8 mg/dL), G. latifolium (110.0 ± 3.3 mg/dL), and V. amygdalina (112.0 ± 3.4 mg/dL). Similarly, TG levels were significantly lowered, with M. oleifera achieving the greatest reduction (82.0 ± 2.4 mg/dL) compared to the negative control group (150.0 ± 3.7 mg/dL).

The effects on LDL levels were equally remarkable, with M. oleifera showing the most substantial decrease to 60.0 ± 2.0 mg/dL, followed by reductions in O. gratissimum, V. amygdalina, and G. latifolium. In contrast, HDL levels, which were reduced in the negative control group (20.0 ± 1.0 mg/dL), increased significantly ($p < 0.05$) with all treatments, particularly with M. oleifera (54.0 ± 1.7 mg/dL). These findings highlight the efficacy of the plant extracts in modulating lipid profiles, with M. oleifera consistently showing the most pronounced effects.

Table 2 Qualitative phytochemical constituents of selected medicinal plants

Phytochemical	V. amygdalina	O. gratissimum	M. oleifera	G. latifolium
Flavonoids	+++	++++	+++	+++
Saponins	+++	+++	+++	++
Alkaloids	++	++	+++	+++
Tannins	+++	+++	++	++
Phenols	++	++	+++	+++

(+ indicates relative abundance: ++ = moderate, +++ = high, ++++ = very high)

Table 3 Quantitative phytochemical composition of selected medicinal plants

Phytochemical	V. amygdalina	O. gratissimum	M. oleifera	G. latifolium
Flavonoids (mg/g)	4.1 ± 0.3	5.2 ± 0.4	3.8 ± 0.2	4.5 ± 0.3
Saponins (mg/g)	2.5 ± 0.2	3.0 ± 0.2	2.8 ± 0.3	3.2 ± 0.3
Alkaloids (mg/g)	2.2 ± 0.2	2.5 ± 0.3	3.5 ± 0.2	2.3 ± 0.2
Tannins (mg/g)	1.8 ± 0.1	2.0 ± 0.2	1.5 ± 0.1	2.0 ± 0.2
Phenols (mg/g)	1.5 ± 0.2	1.8 ± 0.2	2.8 ± 0.3	2.1 ± 0.2

Table 4 Serum lipid profiles and liver enzyme activity of experimental groups

Parameter	Normal control	Negative control	V. amygdalina	O. gratissimum	M. oleifera	G. latifolium
TC (mg/dL)	82.0 ± 2.8	180.0 ± 4.2	112.0 ± 3.4	105.0 ± 2.8	100.0 ± 3.0	110.0 ± 3.3
TG (mg/dL)	60.0 ± 1.9	150.0 ± 3.7	88.0 ± 2.5	85.0 ± 2.2	82.0 ± 2.4	90.0 ± 2.8
LDL (mg/dL)	50.0 ± 1.7	130.0 ± 3.6	68.0 ± 2.3	62.0 ± 2.1	60.0 ± 2.0	70.0 ± 2.4
HDL (mg/dL)	42.0 ± 1.8	20.0 ± 1.0	48.0 ± 1.9	52.0 ± 2.0	54.0 ± 1.7	47.0 ± 1.8
AST (IU/L)	24.0 ± 1.5	56.0 ± 2.3	34.0 ± 1.8	32.0 ± 1.7	30.0 ± 1.5	36.0 ± 1.8
ALT (IU/L)	18.0 ± 1.2	40.0 ± 2.0	24.0 ± 1.3	22.0 ± 1.2	20.0 ± 1.0	26.0 ± 1.4

Liver Enzyme Activities

The methanolic extracts also demonstrated hepatoprotective properties by reducing elevated levels of liver enzymes, AST and ALT, in the hyperlipidemic rats. The negative control group exhibited significantly elevated AST (56.0 ± 2.3 IU/L) and ALT (40.0 ± 2.0 IU/L) levels compared to the normal control group. Administration of the extracts resulted in marked reductions in these enzymes, particularly with M. oleifera, which reduced AST and ALT levels to 30.0 ± 1.5 IU/L and 20.0 ± 1.0 IU/L, respectively.

O. gratissimum and V. amygdalina also displayed significant hepatoprotective effects, achieving AST and ALT levels closer to those of the normal control group. Meanwhile, G. latifolium showed moderate reductions in AST (36.0 ± 1.8 IU/L) and ALT (26.0 ± 1.4 IU/L), though less pronounced than those observed with M. oleifera. These results indicate that the methanolic extracts from the selected plants not only improved lipid metabolism but also provided substantial protection against liver damage associated with hyperlipidemia.

All in all, the selected plant extracts showed significant hypolipidemic and hepatoprotective activities, reducing TC, TG, and LDL levels while enhancing HDL levels and normalising liver enzyme activities. Among the extracts, M. oleifera demonstrated the most potent effects, highlighting its potential for managing hyperlipidemia and associated liver dysfunction (Table 4).

4 Discussion

Proximate Composition

Nutrients play a crucial role in maintaining overall health and supporting various bodily functions. Essential nutrients, including proteins, fats, carbohydrates, vitamins, and minerals, are required in specific amounts to maintain the body's metabolic activities and promote growth, development, and disease prevention. Inadequate intake or deficiencies in these nutrients can lead to malnutrition, which may contribute to the onset of various health problems, including weakened immune systems, growth retardation, and an increased risk of chronic diseases such as cardiovascular diseases and diabetes.[24]

The proximate composition of the selected medicinal plants highlights their varied nutritional profiles, each contributing distinct benefits. M. oleifera stands out with the highest protein content (21.5%), making it an excellent candidate for addressing malnutrition. The high protein and fibre content of M. oleifera positions it as a valuable dietary supplement, particularly for those with protein deficiency.[25] The moisture content of the plants ranged from 7.8% to 9.0%, with V. amygdalina having the highest moisture level (9.0%), which could impact its shelf life due to increased water activity.[26] This makes V. amygdalina more prone to spoilage compared to M. oleifera, which has a lower moisture content (7.8%)

and is likely to remain stable for longer periods. Its low moisture content also suggests better preservation properties, making it suitable for longer storage and consumption in diverse regions.

The fat content, highest in M. oleifera (8.0%) and O. gratissimum (7.2%), suggests that these plants can provide essential fatty acids, which are important for maintaining cellular structure and energy metabolism.[27] These fatty acids play a vital role in overall health and can be beneficial for individuals seeking to increase their intake of healthy fats.

The fibre content was most prominent in V. amygdalina (15.0%), which is a valuable source of dietary fibre. Fibre plays a crucial role in digestive health, helping to lower cholesterol and improve gut function.[28] While M. oleifera (12.0%) and G. latifolium (11.5%) also contain substantial amounts of fibre, their levels are lower than those found in V. amygdalina. These plants can still be significant contributors to dietary fibre intake, particularly in regions where fibre-rich foods are scarce.

Finally, the carbohydrate content, highest in G. latifolium (56.3%) and O. gratissimum (55.3%), gives emphasis to their role as significant energy sources. This makes them particularly useful in traditional diets where carbohydrates are a primary energy source. These findings suggest that these plants could play a key role in providing essential nutrients, improving dietary balance, and addressing nutrient deficiencies in various populations.

Phytochemical Composition

The qualitative phytochemical screening of the selected medicinal plants highlights the diverse levels of bioactive compounds, confirming their traditional medicinal applications. These compounds are recognised for their potent antioxidant and anti-inflammatory properties, playing a key role in reducing oxidative stress and supporting lipid metabolism.[29-31] Such properties make these plants valuable in the prevention and management of oxidative stress-related conditions. Saponins contribute to cholesterol reduction by binding bile acids and enhancing their excretion, which underscores their importance in cardiovascular health and metabolic balance.[32, 33] Similarly, alkaloids are known for their anti-inflammatory and lipid-regulating activities, making them integral to the pharmacological profiles of these plants.[34] Tannins are powerful antioxidants, helping to mitigate oxidative stress and lipid peroxidation, both of which are crucial for metabolic health and disease prevention.[35] Phenols play a critical role in neutralising free radicals and reducing oxidative damage, further emphasising their relevance in traditional medicine.[36] These phytochemical profiles validate the medicinal importance of these plants, demonstrating their potential as sources of antioxidants and bioactive compounds with lipid-regulating and anti-inflammatory properties. Their use in traditional practices aligns with these findings, offering scientific backing for their therapeutic applications.[37, 38]

Similarly, the quantitative phytochemical analysis of the selected medicinal plants reveals varying concentrations of key bioactive compounds, reflecting their distinct phytochemical profiles. Flavonoids were most abundant in O. gratissimum, making it the richest source among the plants studied. High levels were also observed in G. latifolium and V. amygdalina, while M. oleifera recorded the lowest concentration. These findings highlight the antioxidant and cardioprotective potential of O. gratissimum, supporting its use in managing oxidative stress-related conditions.[39] Saponins were highest in G. latifolium. These results validate the traditional use of these plants in cholesterol management and lipid metabolism, as saponins are recognised for their ability to bind bile acids and enhance cholesterol excretion.[40] Alkaloid content was highest in M. oleifera with moderate levels in O. gratissimum and V. amygdalina. They contribute significantly to the lipid-lowering effects and pharmacological activities of these plants, particularly their modulation of metabolic pathways.[41] Tannins showed moderate distribution, with higher concentrations in O. gratissimum and G. latifolium compared to V. amygdalina and M. oleifera. Tannins are renowned for their antioxidant and astringent properties, supporting their role in managing oxidative stress and inflammation.[42] The abundance of phenols in M. oleifera, followed by G. latifolium, O. gratissimum, and V. amygdalina underscores their potential for reducing oxidative stress and providing therapeutic benefits in metabolic disorders.[43, 44] Overall, the results underscore the phytochemical diversity and therapeutic potential of these medicinal plants. The high flavonoid and saponin content in O. gratissimum and the notable high phenolic and alkaloid concentrations in M. oleifera support their traditional roles in antioxidant, lipid-lowering, hepatoprotective, and cardioprotective therapies.[45] These findings provide scientific validation for their use in managing lipid disorders and related health conditions.

Hypolipidemic Activity

All plant extracts significantly reduced TC, TG, and LDL levels while increasing HDL levels compared to the negative control, which served as the hyperlipidemic model. Administration of the extracts resulted in marked reduction of total cholesterol levels, with M. oleifera achieving the most substantial decrease, followed by O. gratissimum, G. latifolium, and V. amygdalina. Triglyceride levels were also significantly ($p < 0.05$) reduced, with M. oleifera showing the greatest effect compared to the negative control. Low-density

lipoprotein levels were significantly ($p < 0.05$) decreased across all treatment groups, with reductions being most pronounced in M. oleifera, while high-density lipoprotein levels increased significantly, particularly with M. oleifera. Rats in the negative control group exhibited significantly elevated AST and ALT levels compared to the normal control group. This increase is attributed to hyperlipidemia-induced liver damage, suggesting oxidative stress and lipid accumulation as contributing factors. M. oleifera demonstrated the most significant hepatoprotective effect. This reduction indicates the potent antioxidative and anti-inflammatory properties of the extract, which may protect hepatocytes from damage caused by lipid peroxidation.[46,47] O. gratissimum and V. amygdalina also effectively reduced liver enzyme levels, with AST and ALT values closer to the normal control group. These effects can be linked to their rich phytochemical profile, including flavonoids and phenols, known for their liver-protective effects.

G. latifolium showed a moderate reduction in AST and ALT, reflecting its potential to alleviate hepatic damage, although less effectively than M. oleifera. The reduction in liver enzyme activity observed in all treatment groups demonstrates the ability of the plant extracts to mitigate liver damage induced by hyperlipidemia. The extracts may enhance liver function by reducing oxidative stress, stabilising hepatocyte membranes, and preventing lipid accumulation. The pronounced effects of M. oleifera highlight its potential as a therapeutic agent for managing liver-related complications of hyperlipidemia.[48] The methanolic extracts from the selected medicinal plants demonstrated significant hypolipidemic activity, as indicated by their effects on serum lipid profiles and liver enzyme levels in experimental animals. The extracts reduced TC, TG, and LDL levels while increasing HDL levels compared to the hyperlipidemic negative control.

5 Conclusion

The findings of this study highlight the significant hypolipidemic and hepatoprotective activities of methanolic extracts from M. oleifera, O. gratissimum, V. amygdalina, and G. latifolium. Among the studied plants commonly used in Southern Nigeria, M. oleifera consistently showed the most pronounced effects on lipid metabolism and liver enzyme activity, followed by O. gratissimum, V. amygdalina, and G. latifolium. These extracts significantly improved serum lipid profiles and reduced liver enzyme levels in hyperlipidemic rats. While these results suggest potential therapeutic benefits, further clinical studies are required to determine their efficacy and safety in humans.

Declarations

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Not applicable.

Artificial Intelligence Disclosure
The authors confirm that no artificial intelligence (AI) tools were used in the preparation of this manuscript.

Authors' Contributions
All the authors contributed equally to several sections of the study, including the design, methodology, procurement of materials and assay kits, processing of results, discussion, and final submission.

Availability of Data and Materials
The data that support the findings of this study are available upon request from the corresponding author.

Conflict of Interest
The authors have no conflict of interest in this study.

Consent for Publication
Not applicable.

Ethical Considerations
Ethical approval for this study and the use of animals was granted by the Directorate of Research and Quality Assurance, Federal University Otuoke, Bayelsa State, via a letter referenced DRQA/ Ethical approval for the study, including the use of animals, was obtained from the Directorate of Research and Quality Assurance, Federal University Otuoke, Bayelsa State, under the Code of Ethics DRQA/FUO/0121/10/11/24.

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