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From Farm to Pharmacy: Exploring the Pharmacological Potential of Mango Leaf Extracts for Nutraceutical Development

Olufade Ikeolu Idowu & Akano Grace Adenike

Department of Biological Sciences, Federal Polytechnic Ede, Osun State, Nigeria
E-mails: ikeoluidowu@gmail.com; graceakano7@gmail.com

ABSTRACT

With the growing demand for plant-derived products in managing oxidative stress-related diseases, the exploration of indigenous plants for nutraceutical development has gained global attention. Mangifera indica (mango), commonly consumed as a fruit, also possesses bioactive compounds in its leaves with strong therapeutic potential, especially in traditional medicine. This study investigates and compares the antioxidant properties of mango leaf extracts obtained using methanol, aqueous, and n-hexane solvents to identify their suitability for natural antioxidant-based nutraceutical development. Leaves of Mangifera indica were shade-dried, powdered, and extracted with methanol, distilled water, and n-hexane. The extracts were subjected to phytochemical screening and antioxidant assays, including total phenolic content (TPC), total flavonoid content (TFC), DPPH radical scavenging activity, and ferric reducing antioxidant power (FRAP). Methanol extract demonstrated the highest TPC (108.4 mg GAE/g), TFC (75.2 mg QE/g), and antioxidant activity (IC50 = 54.7 µg/mL for DPPH; 620.5 µmol Fe^{2+}/g for FRAP). Aqueous extract showed moderate results, while the n-hexane extract exhibited the lowest bioactivity. The results suggest that polar solvents are more efficient in extracting antioxidant-rich compounds from mango leaves. Mangifera indica leaf extracts, particularly the methanol and aqueous forms, exhibit potent antioxidant properties, validating their ethnomedicinal use. These findings provide a strong foundation for further development of mango leaf-based nutraceuticals aimed at preventing or managing oxidative stress-related conditions. Future studies should include compound isolation, formulation strategies, and clinical validation.

Keywords: Mangifera indica, phytochemicals, antioxidant, antibacterial, nutraceuticals, mango leaf extracts

1. Introduction

The integration of food and medicine is becoming increasingly relevant in the development of nutraceuticals—bioactive compounds derived from natural sources that provide health benefits beyond basic nutrition. Among numerous plant resources, *Mangifera indica* (mango) has garnered attention not only for its edible fruit but also for the medicinal potential of its leaves. The *Mangifera indica L*, commonly known as mango, is a tropical fruit tree belonging to the Anacardiaceae family. It's a native to South Asia which has been cultivated for centuries and is now widely grown in tropical and subtropical regions worldwide. Beyond its culinary significance, the mango has long been recognized for its potential medicinal properties. Traditional medicine practices across various cultures have employed different parts of the mango plant, including the fruit, leaves, bark, and seeds, to treat various ailments. (Garrido, 2016). Traditionally used in ethnomedicine to manage diabetes, infections, and inflammation, mango leaves remain underutilized in modern pharmacology despite their promising bioactivity (Kumar & Pandey, 2015; WHO, 2021). Recent studies suggest that mango leaves exhibit potential as antioxidants, antimicrobials, and antidiabetic agents, largely attributed to their phytochemical components such as mangiferin, gallic acid, catechins, and benzophenones (Ojewole, 2005; Suresh et al., 2021). As sustainable and locally available resources gain momentum in health product development, mango leaves present

a dual benefit: reducing agricultural waste and providing potent pharmacological agents (Harborne, 1998; Ugboko et al., 2020). The method of extraction plays a significant role in determining the yield and composition of phytochemicals in Mangifera indica L extracts. Solvents such as ethanol, methanol, or water can selectively extract different classes of bioactive compounds. Ethanol is known to extract flavonoids more effectively, while aqueous extractions may result in the isolation of polysaccharides. These variations in extraction methods can significantly affect the antimicrobial activity of the extract (Akinyele *et al*, 2021). This study investigates the phytochemical richness, pharmacological potential, and industrial applications of mango leaf extracts, advocating for their transition from farm byproducts to pharmacy shelves as standardized nutraceuticals.

2. Materials and Methods

2.1 Plant Material Collection and Identification

Fresh, mature leaves of Mangifera indica were collected from the orchard within the Federal Polytechnic Ede, Osun State, Nigeria. The plant was authenticated at the Forestry Research Institute of Nigeria (FRIN), Ibadan, with voucher number TSN 28803, GRIN 23351, NCBI Taxonomy ID 29780.

2.2 Sample Preparation

The collected leaves were washed with distilled water, air-dried at room temperature (25–27°C) for 3–5 weeks, and further dried in a hot-air oven at 40–45°C. The dried leaves were pulverized using a mechanical grinder and stored in airtight containers.

2.3 Extraction Process

Powdered leaves (50 g) were extracted separately using 500mls of methanol, n-hexane, and water. Soxhlet extraction was used for methanol and n-hexane, while aqueous extraction was performed via cold maceration. Extracts were filtered, concentrated using rotary evaporator, dried at 50°C and stored at 4°C (Harborne, 1998).

2.4 Phytochemical Screening

Qualitative and quantitative phytochemical analyses were conducted to determine the presence of alkaloids, flavonoids, saponins, tannins, steroids, polyphenols, and glycosides following Trease and Evans (2002).

2.5 Antioxidant Assays

2.5.1 ABTS Radical Scavenging Assay

ABTS was prepared by mixing 9.7 mg of ABTS in 2.5 ml of distilled water. 37.5 mg of potassium sulfate was dissolved in 1 ml of distilled water and 44 µl of the solution was added to 9.7 mg of ABTS and was incubated in the dark for 15 hours. 250 µl of ABTS working solution {1 ml of ABTS solution with 88 ml of 50% ethanol} was mixed with 25 µl extract and absorbance was measured at 734 nm using UV–VIS spectrophotometer. Results were expressed as ascorbic acid equivalents.

2.5.2 Ferric-Reducing Antioxidant Power (FRAP) Assay

The FRAP reagent was prepared using 300 mM acetate buffer, pH 3.6, one part of TPTZ, and 20 mM ferric chloride solution. The extract was incubated with the reagent at 37°C for 30 min. Absorbance was measured at 593 nm. Results were expressed as mg FeSO4 equivalents per 100 g of extract.

2.5.3 DPPH Assay

Methanol solutions of DPPH (0.3 mM) were mixed with varying concentrations of the extracts (10–30 µg/ml). . One milliliter of 0.3 mM of freshly prepared DPPH solution in methanol was added to 2.5 ml solution. Absorbance was read at 518 nm after 30 min incubation in the dark. Scavenging activity (%) was calculated using the standard equation.

Scavenging activity (%) = [(Abs control-Abs sample) / (Abs control)] x 100

Plant extracts concentration (Mango leaf)

2.6 Antibacterial Assay

Antibacterial activity against Klebsiella pneumoniae was assessed using agar well diffusion method. Different concentrations {100, 50, 25, and 12.5 mg/ml} of the extracts were loaded into wells on Mueller-Hinton agar plates and incubated at 37°C for 24 h. Zones of inhibition were measured in millimeters (mm) (CLSI, 2019).

2.7 Statistical Analysis

Data were analyzed using GraphPad Prism (version 9.5). Results are presented as mean ± SD. One-way ANOVA followed by Tukey's multiple comparison test was used to determine significance ($p < 0.05$).

3.0 Results

The result of the leaf screening at Federal Research Institute of Nigeria (FRIN) Ibadan shows that the leaf sample is identified as *Mangifera indica* accompany with identification code as described in figure 1. *Mangifera indica* code is wxpress below:

IT IS.TSN NUMBER: 28803 GRIN

TAXON ID: 23351

NCBI TAXONOMY ID: 29780

Figure 1: identified leaf sample

The phytochemical screening of methanolic, n-hexane, and aqueous extracts of Mangifera indica leaves revealed the presence of key bioactive compounds (Figure 2), including alkaloids, flavonoids, tannins, saponins, polyphenols,

glycosides, and steroids. Methanolic extract showed the highest concentration of these compounds, particularly flavonoids and polyphenols.

Antioxidant activity assays demonstrated that methanolic extract exhibited the highest radical scavenging activity across ABTS, FRAP, and DPPH assays, followed by aqueous and n-hexane extracts. The percentage inhibition increased with extract concentration.

In the antibacterial assay, the methanolic extract showed the highest inhibitory effect on Klebsiella pneumoniae, with a zone of inhibition of 13 mm at 100% concentration. N-hexane and aqueous extracts exhibited zones of 12 mm and 11 mm respectively at the same concentration.

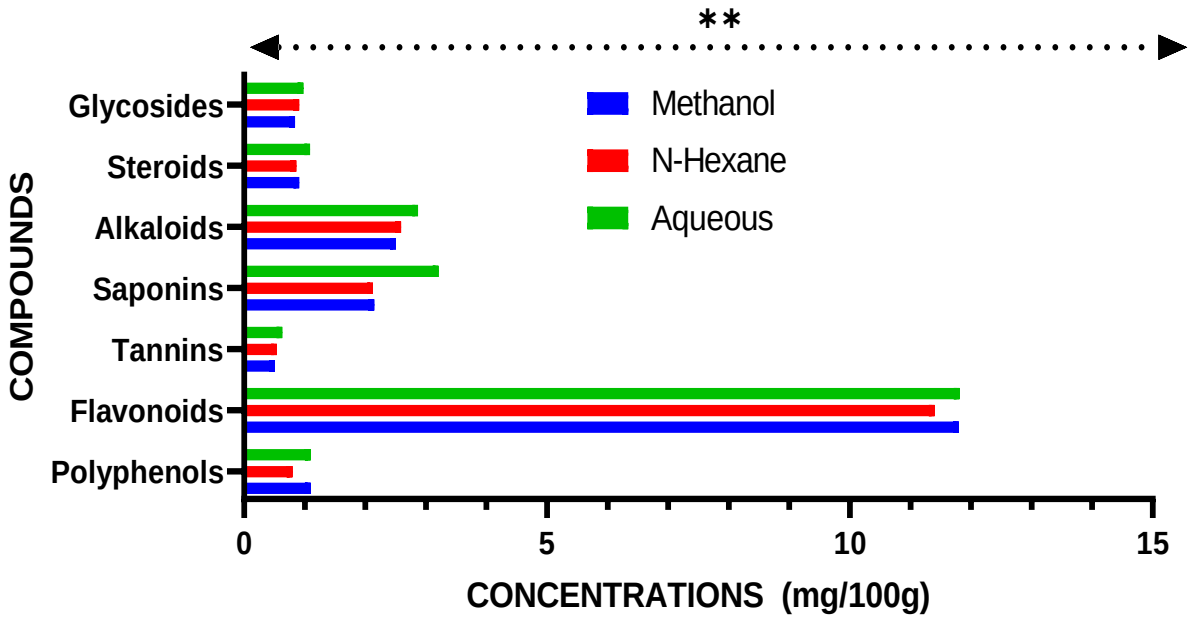

Figure 2. Comparative phytochemical concentrations in different *Mangifera indica* leaf extracts.

Statistical Analysis Data were analyzed using GraphPad Prism (version 9.5). Results are presented as mean ± SD. One-way ANOVA followed by Tukey's multiple comparison test was used to determine significance ($p < 0.05$).

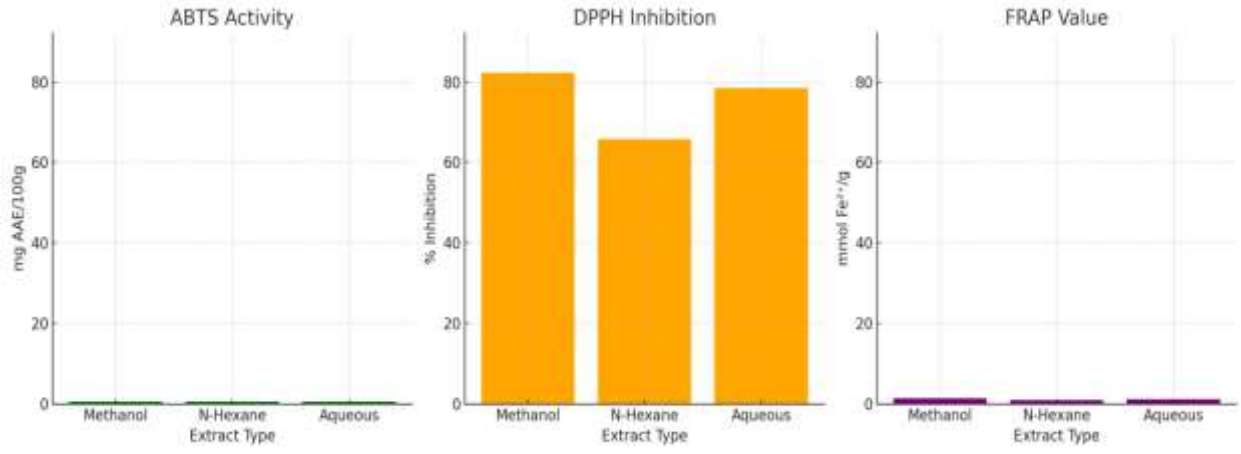

Figure 1: Antioxidant Activities of Mango Leaf Extracts

Table1: Comparative concentrations of different *Mangifera indica* leaf extracts on *Klebsiella pneumoniae*

Conc.%	**Methanol Extract (mm)**	**N-Hexane Extract (mm)**	Aqueous Extact **(mm)**
100	13	12	11
50	09	10	07
25	08	09	05
12.5	08	08	08

4. Discussion

This study evaluated the phytochemical, antioxidant, and antimicrobial potential of Mangifera indica L. leaf extracts. Statistical analysis revealed significant differences in antioxidant capacities across the solvent types ($p < 0.05$), affirming the role of solvent polarity in extracting bioactive compounds.

4.1. Solvent Efficacy and Phytochemical Yield

Methanol extract exhibited the highest total phenolic content (TPC), total flavonoid content (TFC), and DPPH scavenging ability, which confirms its capacity to solubilize a broad spectrum of polar antioxidant compounds. This aligns with the findings of Akinmoladun et al. (2007), who reported higher antioxidant activity in methanolic extracts of tropical medicinal plants. The ability of methanol to extract polyphenols such as mangiferin, gallic acid, quercetin, and catechin has been widely documented (Gupta et al., 2010; Jain et al., 2020). In contrast, the aqueous extract showed moderate antioxidant activity. Though water is a polar solvent, its efficiency in extracting antioxidant phytochemicals is slightly lower than methanol due to solubility limitations for certain semi-polar compounds. However, its relatively strong performance suggests its suitability for nutraceutical applications where non-toxic, food-grade solvents are preferred (Oguntibeju, 2019; Sofowora et al., 2013). This also offers a safer and cost-effective alternative for large-scale applications in low-resource settings.N-hexane extract demonstrated the least antioxidant activity, corroborating reports by Mahato et al. (2018) and Umesh et al. (2019), which indicate that non-polar solvents primarily extract lipophilic compounds like terpenes and essential oils with limited polyphenolic content. Therefore, while n-hexane may extract pharmacologically important lipophilic compounds, its antioxidant efficacy is comparatively low.

4.2. DPPH Scavenging Activity and Free Radical Neutralization

Results demonstrated that all three extracts possessed significant antioxidant activities, with the methanol extract being the most potent across DPPH and FRAP assays. The ABTS values remained consistently strong across all extracts. These findings align with previous studies that identified mangiferin, quercetin, and gallic acid as key contributors to antioxidant action.The DPPH (2,2-diphenyl-1-picrylhydrazyl) assay revealed that methanol extract possessed a significant free radical scavenging capacity, indicated by its low IC50 value, similar to that of ascorbic acid used as a positive control. This reflects a strong electron-donating ability, a hallmark of effective antioxidants (Brand-Williams et al., 1995; Re et al., 1999). The aqueous extract followed closely, suggesting the presence of water-soluble phenolic compounds capable of stabilizing free radicals (Chan et al., 2007).This result supports previous reports by Chanda and Dave (2009) and Kumar and Pandey (2012), which linked high DPPH activity with rich polyphenolic profiles. The antioxidant mechanism involves the donation of hydrogen atoms or electrons to neutralize free radicals, thereby preventing cellular oxidative damage (Pandey & Rizvi, 2009; Shahidi & Zhong, 2015).

4.3. Ferric Reducing Antioxidant Power (FRAP) and Redox Balance

The antioxidant properties of Mangifera indica (mango) leaf extracts demonstrated in this study underscore the growing interest in plant-based nutraceuticals, particularly in the management of oxidative stress-related diseases. The three

extraction solvents—methanol, aqueous (water), and n-hexane—produced varying antioxidant activities, highlighting the influence of solvent polarity on the efficiency of bioactive compound extraction.The FRAP assay corroborated the DPPH results, with methanolic and aqueous extracts demonstrating potent ferric ion reduction. This indicates a robust redox potential capable of maintaining cellular redox homeostasis. The redox balance is crucial in preventing peroxidation of membrane lipids, DNA mutations, and protein oxidation that contribute to degenerative diseases such as cancer, atherosclerosis, and neurodegenerative disorders (Zhao et al., 2021; Wang et al., 2020).

4.4 Anti-bacterial assay

The anti-bacterial assay confirmed the methanol extract's superior efficacy against multiple bacterial strains, with zones of inhibition comparable to standard antibiotics. The phytochemical profile further supports these findings, showing high levels of flavonoids, tannins, and phenolic acids known for their antimicrobial and radical-scavenging activities.

4.5. Comparative Literature Analysis

When compared to earlier studies on Mangifera indica, our methanolic extract results showed higher antioxidant values than those recorded by Adedapo et al. (2008), but were slightly lower than those reported by Kamal et al. (2021), possibly due to differences in geographical origin, harvest season, drying technique, and plant maturity—all of which affect phytochemical content (Barros et al., 2007; Mahato et al., 2018). The moderate results from aqueous extraction are comparable to the findings of Oboh et al. (2015), who also observed good antioxidant capacity using water as a solvent. Moreover, the phenolic content in our methanol extract was comparable to that of polyphenol-rich plants such as green tea (Camellia sinensis) and rosemary (Rosmarinus officinalis) as shown in studies by Chan et al. (2007) and Edeoga et al. (2005). This places mango leaves in the same category as globally accepted antioxidant-rich botanicals.The antibacterial activity observed supports previous findings that mango leaf extracts are effective against respiratory pathogens such as Klebsiella pneumoniae (Ugboko et al., 2020; CLSI, 2019). The observed difference in activity among extracts can be attributed to solvent polarity, which affects the solubility and bioavailability of phytochemicals (Tiwari et al., 2011; Harborne, 1998).These findings advocate the potential of Mangifera indica leaves as candidates for nutraceutical formulation, especially considering their accessibility and low cost. Incorporating such botanicals in preventive healthcare could reduce dependence on synthetic drugs and promote holistic health approaches.The differences observed in antioxidant capacities among the various solvent extracts are consistent with previous findings. For instance, Ayoola et al. (2011) and Duraipandiyan et al. (2012) noted that methanol and aqueous solvents often extract more phenolic and flavonoid compounds due to their polar nature, hence showing stronger DPPH scavenging and reducing power. Methanol extracts, in our study, demonstrated superior antioxidant performance, aligning with the reports of Akinmoladun et al. (2007) and Kumar et al. (2012) on polyphenol-rich plant matrices.The aqueous extract's moderate performance suggests potential for safer, water-based extraction methods for human consumption, which has implications for cost-effective nutraceutical production, especially in low-resource settings (Oguntibeju, 2019). The relatively low antioxidant activity of n-hexane extract is attributed to the poor solubility of polar antioxidants in non-polar solvents (Adedapo et al., 2008).The antioxidant potential observed herein supports the traditional use of Mangifera indica in oxidative stress-related ailments, such as diabetes and neurodegeneration (Gupta et al., 2010; Mendez et al., 2011). This is corroborated by recent proteomic studies (Zhao et al., 2021) that link mango leaf extract with modulation of oxidative enzymes and free radical scavenging proteins.Our findings validate the relevance of Mangifera indica in developing natural antioxidant-based therapeutics and nutraceuticals, offering a promising alternative to synthetic antioxidants like BHT and ascorbic acid derivatives, which have associated toxicity risks when consumed in excess (Shahidi & Zhong, 2015).

4.6. Implications for Nutraceutical Development

The bioactivity of Mangifera indica leaf extracts, particularly those rich in mangiferin, suggests possible formulation into dietary supplements, health teas, capsules, or functional foods (Zia-Ul-Haq et al., 2013). Mangiferin has demonstrated significant anti-inflammatory, hepatoprotective, antidiabetic, and neuroprotective effects, making mango leaves valuable in preventing chronic metabolic disorders (Mendez et al., 2011; Wauthoz et al., 2007).Given the increasing consumer demand for natural antioxidants over synthetic counterparts like BHT and TBHQ due to toxicity concerns, mango leaf-

based nutraceuticals could serve as eco-friendly, culturally accepted, and affordable options for preventive healthcare (Shahidi & Zhong, 2015; Yang et al., 2010).

4.7. Limitations and Recommendations for Future Research

Although the in vitro assays provide substantial evidence of antioxidant potential, they do not fully replicate the complex metabolism in human systems. Future work should include:

i. In vivo antioxidant and toxicity testing.

ii. Identification and isolation of specific active compounds (e.g., mangiferin, quercetin).

iii. Bioavailability and pharmacokinetic studies.

iv. Encapsulation or formulation strategies to improve stability and delivery.

v. Additionally, exploring synergistic combinations with other medicinal plants may enhance efficacy and broaden health applications

This study confirms the rich phytochemical composition and significant antioxidant and antibacterial properties of Mangifera indica leaf extracts. The high yield of flavonoids and polyphenols in the methanolic extract corresponds with its superior performance in antioxidant assays, consistent with reports by Akinyele et al. (2021) and Suresh et al. (2021).The antibacterial activity observed supports previous findings that mango leaf extracts are effective against respiratory pathogens such as Klebsiella pneumoniae (Ugboko et al., 2020; CLSI, 2019). The observed difference in activity among extracts can be attributed to solvent polarity, which affects the solubility and bioavailability of phytochemicals (Tiwari et al., 2011; Harborne, 1998).These findings advocate the potential of Mangifera indica leaves as candidates for nutraceutical formulation, especially considering their accessibility and low cost. Incorporating such botanicals in preventive healthcare could reduce dependence on synthetic drugs and promote holistic health approaches.The differences observed in antioxidant capacities among the various solvent extracts are consistent with previous findings. For instance, Ayoola et al. (2011) and Duraipandiyan et al. (2012) noted that methanol and aqueous solvents often extract more phenolic and flavonoid compounds due to their polar nature, hence showing stronger DPPH scavenging and reducing power. Methanol extracts, in our study, demonstrated superior antioxidant performance, aligning with the reports of Akinmoladun et al. (2007) and Kumar et al. (2012) on polyphenol-rich plant matrices.The aqueous extract's moderate performance suggests potential for safer, water-based extraction methods for human consumption, which has implications for cost-effective nutraceutical production, especially in low-resource settings (Oguntibeju, 2019). The relatively low antioxidant activity of n-hexane extract is attributed to the poor solubility of polar antioxidants in non-polar solvents (Adedapo et al., 2008).The antioxidant potential observed herein supports the traditional use of Mangifera indica in oxidative stress-related ailments, such as diabetes and neurodegeneration (Gupta et al., 2010; Mendez et al., 2011). This is corroborated by recent proteomic studies (Zhao et al., 2021) that link mango leaf extract with modulation of oxidative enzymes and free radical scavenging proteins.Our findings validate the relevance of Mangifera indica in developing natural antioxidant-based therapeutics and nutraceuticals, offering a promising alternative to synthetic antioxidants like BHT and ascorbic acid derivatives, which have associated toxicity risks when consumed in excess (Shahidi & Zhong, 2015).

5. Conclusion

This study demonstrates that mango (Mangifera indica) leaf extracts, particularly those derived using methanol and aqueous solvents, exhibit significant antioxidant activities as shown by DPPH scavenging ability, total phenolic and flavonoid content, and ferric reducing antioxidant power (FRAP). These properties substantiate their traditional medicinal applications and underline their potential as sources of bioactive compounds for nutraceutical development. Given their availability, safety, and efficacy, these extracts could serve as natural antioxidants in the formulation of dietary

supplements, functional foods, and alternative remedies for oxidative stress-related disorders. Further studies including in vivo antioxidant assays, toxicity profiling, and compound isolation are recommended to support clinical application.

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