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Research Article

Nutritional composition and antioxidant properties of *Moringa oleifera* Lam.: a global superfood perspective

Smitaa Basole[1], Gireesh Tripathi[2], Ananta Kumar Acharya[3], Kevileto Rote[4] and Bhagwati Prashad Sharma[5*]

[1]Department of Botany, Balbhim College, Beed, Maharashtra, India

[2]School of Pharmacy, Aryavart University, Near Raja Bhoj Airport, NH 46, Sehore, Madhya Pradesh, India

[3]Ex Joint Director (Ayurveda), Sundargarh, Odisha, India

[4]Research, Demonstration and Training Centre (Soil & Water Conservation Department), Kohima, Nagaland, India

[5]Department of Botany, Sidharth Government College, Nadaun, Himachal Pradesh, India

*Email-Id: bp76sharma@gmail.com; ORCID: https://orcid.org/0000-0002-8134-9807

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Abstract: The issues of global malnutrition, micronutrient deficiencies and chronic diseases driven by oxidative stress like heart disease, diabetes and cancer demand for sustainable plant-based solutions. However, the evidence comparing different extraction methods is still quite scattered. *Moringa oleifera* Lam., the 'miracle tree,' offers a compelling solution. This incredible plant is enriched with amino acids, vitamins, minerals and phenolic antioxidants and it can be grown easily and affordably in tropical and subtropical areas. The present study took a comprehensive approach that included a systematic literature review, experimental analysis of DPPH radical scavenging in *M. oleifera* fruit pulp extracts using three different solvent systems (ranging from 0.125 to 1.0 mg/mL) and field survey data on how it's cultivated and used traditionally. The ethanolic extracts showed the best DPPH inhibition at 89.32% when tested at 1.0 mg/mL, followed by aqueous extracts at 78.27% and n-hexane extracts at 70.52%. All methods demonstrated a clear positive dose-response relationship across the concentrations tested. The present study highlights the nutritional benefits and antioxidant strength of *M. oleifera*, providing a solid evidence-based reference for developing nutraceuticals, food fortification and supplementation strategies aimed at addressing micronutrient deficiencies and the burden of oxidative diseases in at-risk populations.

Keywords: Chronic diseases, global malnutrition, micronutrient deficiency, miracle tree and nutraceuticals

Introduction

Moringa oleifera Lam., belongs to Moringaceae family, often referred to as the "miracle tree" or "drumstick tree," has become one of the most nutritionally important plants of the 21st century (Bilali et al., 2024; Sharma et al., 2025). This remarkable tree is native to the sub-Himalayan areas of northwestern India and is now widely grown in tropical and subtropical regions across Asia, Africa and Latin America (Karvande et al., 2025). For centuries, it has played a vital role in traditional medicine, food security efforts and indigenous healthcare practices (Pareek et al., 2023; Soto et al., 2025).

Figure 1: Fruits of *M. oleifera*

The nutritional benefits of *Moringa* are truly impressive - just its leaves alone can provide around 25–30% crude protein by dry weight, including all nine essential amino acids like lysine, methionine and tryptophan, which are often lacking in plant-based diets (Islam et al., 2021; Kumar et al., 2025). The leaves are enriched with beta-carotene, vitamin C, tocopherols and B-complex vitamins, along with essential minerals such as calcium, iron, potassium and zinc - all of which consistently outshine those found in commonly eaten vegetables (Buyel et al., 2025). Beyond just macronutrients and micronutrients, *M. oleifera* is rich in bioactive phytochemicals like quercetin, kaempferol, chlorogenic acid, caffeic acid and the isothiocyanate moringin, which together offer powerful antioxidant, anti-inflammatory, antidiabetic and antimicrobial benefits (Verma et al., 2025). The health benefits of *M. oleifera* are impressive, impacting various bodily systems and making it particularly important in addressing the global challenge of non-communicable diseases (Milla et al., 2021). Leaf extracts from this plant have shown notable blood sugar-lowering effects by inhibiting enzymes like α-amylase and α-glucosidase, which positions it as a potential ally in managing diabetes (Nova et al., 2020). The oil extracted from its seeds, rich in oleic acid (65–80%), provides heart health benefits similar to those of olive oil (Cervera-Chiner et al., 2024). Community studies in Sub-Saharan Africa and South Asia have highlighted improvements in nutritional health among children facing moderate acute malnutrition and better iron levels in pregnant and breastfeeding women, emphasizing *M. oleifera's* crucial role in global food security (Rotella et al., 2023; Tarigan et al., 2026). To thoroughly explore this multifaceted importance, the current study employs a comprehensive approach that includes a systematic literature review, experimental analysis of *M. oleifera* fruit pulp extracts using DPPH radical scavenging across various solvent systems (n-hexane, ethanol and water) at concentrations from 0.125 to 1.0 mg/mL and field surveys on cultivation and traditional uses in tropical and subtropical areas. The results aim to provide a well-rounded, evidence-based resource for researchers, nutritionists and policymakers, with practical applications in developing nutraceuticals, food fortification initiatives and targeted dietary supplementation strategies - especially in regions grappling with high rates of micronutrient deficiencies and oxidative stress-related diseases. However, despite its impressive profile, there’s still limited and inconsistent scientific documentation regarding its antioxidant strength across various extraction methods. The present study aims to thoroughly assess and document the nutritional makeup and antioxidant properties of *M. oleifera* from a global superfood perspective, helping to bridge the gap between traditional wisdom and evidence-based nutritional science.

Methodology

The present study integrates field surveys, experimental tests and a thorough review of published literature on *M. oleifera*. We meticulously searched scientific databases like Google Scholar, Scopus, PubMed and Web of Science to gather peer-reviewed articles, review papers, ethnobotanical surveys and pharmacological studies. Our search utilized keywords such as "*M. oleifera*," "medicinal uses," "nutritional compounds" and "potent scavenging bioactive compounds" to pinpoint relevant publications. Field surveys took place in March-May 2026, right during *M. oleifera’s* peak fruiting season. Authors identified the plant specimen based on the regional flora guide by Saxena and Brahmam (1994). Furthermore, current survey conducted experimental analyses to assess and confirm the antioxidant potential of *M. oleifera* fruits using the DPPH free radical scavenging assay.

Antioxidant DPPH assay

Collection of *M. oleifera* fruits were done from nearby Mahanadi areas of Cuttack District, Odisha, India. The fruit was thoroughly washed, cut and the pulp was macerated with different solvents like n-hexane, ethanol and distilled water separately (Dintu et al., 2026; Figures 1 & 2). The DPPH radical scavenging assay was used to evaluate the filtered extract following Dehar et al., (2022) with minor modifications. 1 ml of 0.1 mM DPPH solution prepared in methanol was added to prepared concentrations of aqueous, ethanolic and n-hexane extracts (1.0, 0.5, 0.25 and 0.125 mg/mL) using the respective solvents adjusting the final volume to 2 ml. 1 mL 0.1 mM DPPH in 1 mL methanol was used as control. Sample blanks (without DPPH) were used for background correction of absorbance. Reaction mixtures were exposed to dark incubation at room temperature for 20 minutes and the absorbance was spectrophotometrically taken at 517 nm. Percentage of radical scavenging activity was calculated using the following formula (Table 1).

% Inhibition= A_0 - A_s /A_0× 100

Where, A_0 is the absorbance of the control and A_s is the absorbance of the sample after blank correction.

Figure 2: *M. oleifera*'s fruit pulp for antioxidant DPPH assay

Results and discussion

The DPPH radical scavenging activity of *M. oleifera* fruit pulp extracts, tested across three different solvent systems and four concentrations, is detailed in Table 1. The ethanolic extracts showed the most significant inhibition at 89.32% when at a concentration of 1.0 mg/mL, followed by the aqueous extracts at 78.27% and n-hexane extracts at 70.52%, all at the same concentration. Each of the three systems demonstrated a clear positive dose-response relationship, with inhibition values gradually decreasing to 79.35%, 71.54%, and 66.05% respectively at 0.125 mg/mL (Figure 3). The result confirmed that the free radical scavenging behavior is indeed concentration-dependent across all the solvent fractions.

The impressive antioxidant capabilities of ethanolic extracts can be attributed to how well they dissolve phenolic and flavonoid compounds - especially quercetin, kaempferol and chlorogenic acid - which act as key hydrogen donors in DPPH quenching reactions. The minimal inhibition seen in n-hexane extracts is due to the extraction of lipophilic components that have a weaker ability to scavenge radicals. In contrast, aqueous extracts displayed moderate activity by recovering water-soluble polyphenols. These results align with existing research on *M. oleifera*, where ethanolic fruit pulp extracts are known for their strong antioxidant properties, thanks to their abundant glucosinolate and isothiocyanate content. All in all, these findings confirmed that *M. oleifera* is a powerful natural source of antioxidants and highlight ethanol as the best solvent for extracting bioactive compounds that are important for nutraceuticals and food fortification.

Table 1: Antioxidant potential of *M. oleifera* fruit pulp extracts

Concentration (in mg/ml)	Inhibition (%)		
	n-Hexane	Ethanolic	Aqueous
1.0	70.52	89.32	78.27
0.5	69.44	84.71	77.15
0.25	68.31	82.68	74.53
0.125	66.05	79.35	71.54

Research gaps

While there have been some promising findings regarding the antioxidant properties of *M. oleifera* fruit pulp extracts, there are still significant gaps in research. We still need to identify the phytochemicals, determine the IC_{50} values and validate results through multiple assays beyond just DPPH. Additionally, there's a lack of documentation on the bioavailability, seasonal and geographic variations, processing impacts and toxicological profiles of the fruit pulp fractions. Most importantly, there are no clinical trials that confirm the in vitro antioxidant effects in human populations.

Future aspects

Future studies should focus on conducting clinical trials to confirm the antioxidant benefits of *M. oleifera* fruit pulp extracts in living organisms. It's also crucial to carry out thorough phytochemical profiling and determine the IC_{50} values. Additionally, exploring aspects like bioavailability, the best solvent systems, seasonal changes and the effects of processing will be key to enhancing its use in nutraceutical products and therapeutic supplements.

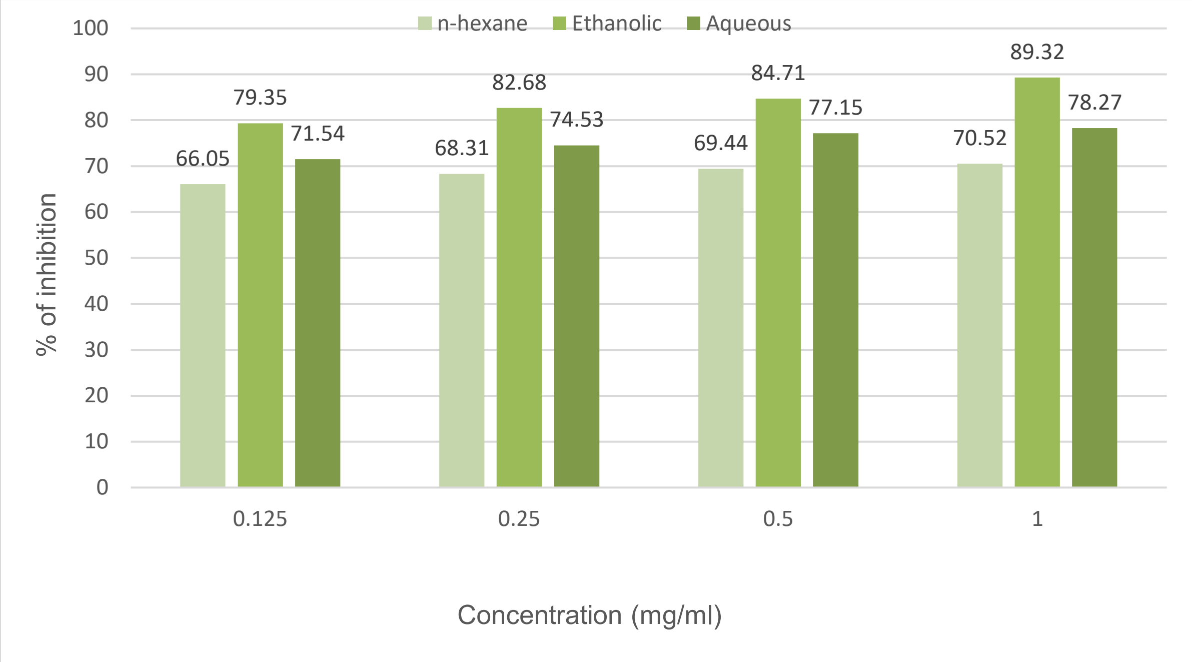

Figure 3: Antioxidant activity of *M. oleifera* fruit pulp extracts

Conclusion

The extracts from *M. oleifera* fruit pulp showed a remarkable ability to scavenge DPPH radicals in a concentration-dependent manner, with the ethanolic extracts achieving the highest inhibition rate of 89.32% at a concentration of 1.0 mg/mL. These results highlight its potential as a powerful natural antioxidant, paving the way for its use in developing nutraceuticals, enhancing food products and supporting evidence-based dietary supplementation strategies around the world.

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