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Review Article

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Bioactive Compounds and Medicinal Applications of *Moringa oleifera:* A Review

Ibtissem BENGHALEM[1], Zoubida MAMI-SOUALEM[1], Radjaa Kaouthar MEZIANE[1], Mansouria Souria BENDEDDOUCHE[2].

[1]Laboratory of Natural Products, University of Abou Bekr Belkaid, Tlemcen, Algeria

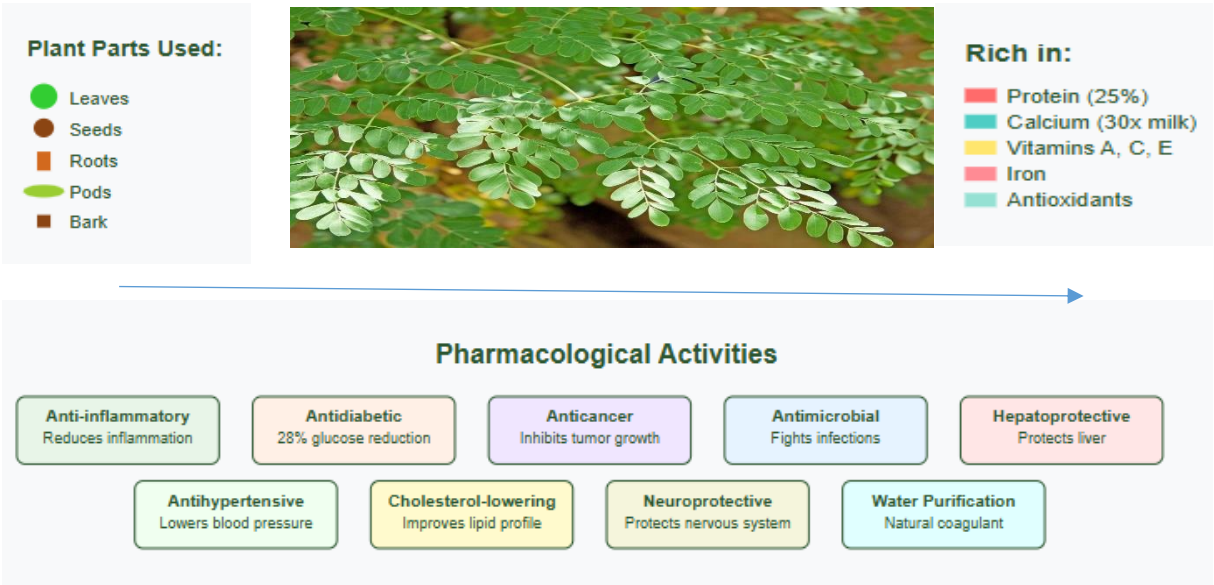
[2] Research Laboratory of Process Engineering, Materials and Environment (LGPME), Sidi Bel Abbes University.

***Corresponding author:** benghalem.ibtissem@yahoo.fr

Highlights

- Superior Nutrition: Contains 25% protein and 30x more calcium than milk, plus high levels of vitamins A, C, and E.
- Broad Medicinal Uses: Demonstrates anti-inflammatory, antimicrobial, anticancer, antidiabetic, and liver-protective properties.
- Proven diabetes benefits: clinical studies show a 28% reduction in blood sugar and improved cholesterol levels in diabetic patients.
- Excellent safety: no adverse effects reported in human studies, with consistently low toxicity in animal trials.
- The multi-purpose plant functions as food, medicine, water purifier, and oil source while thriving in drought conditions.

Graphical Abstract



Abstract

Moringa oleifera is increasingly recognized as a "miracle tree" due to its exceptional nutritional and medicinal properties. This plant serves as a valuable natural resource, not only enhancing dietary intake but also aiding in the prevention and treatment of a variety of health conditions. Rich in easily absorbable proteins, iron, calcium, potassium, and essential vitamins such as A, C, and E, *M. oleifera* also contains significant levels of bioactive compounds, including polyphenols. Various parts of the plant such as seeds, roots, leaves, flowers, bark, and buds, demonstrate a wide array of pharmacological activities, including anti-inflammatory, antimicrobial, anticancer, antihypertensive, antihyperlipidemic, antidiabetic, hepatoprotective, and neuroprotective effects. This review aims to provide a thorough overview of the current global research on *M. oleifera*, covering its phytochemical composition, pharmacological properties, toxicological data, and ethnomedicinal uses. Furthermore, it emphasizes its potential phytopharmaceutical applications and presents a case study illustrating its effectiveness as a natural coagulant in water purification. By synthesizing these findings, this review aims to inspire further research into the nutritional and therapeutic benefits of *M. oleifera*.

Key words: *Moringa oleifera*, Nutritional properties, Therapeutic applications, Bioactive compounds, Medicinal plants.

1. Introduction

In recent decades, the search for natural sources of nutrition and therapeutics has intensified, particularly in regions facing food insecurity and limited access to conventional medicine. *M. oleifera*, commonly referred to as the “miracle tree,” has gained global attention due to its remarkable nutritional profile and wide range of pharmacological applications. Native to the Indian subcontinent and now cultivated throughout tropical and subtropical regions, this fast-growing, drought-resistant tree is considered one of the most valuable multipurpose plants (Bose et al., 2023).

Almost every part of the plant, including the leaves, seeds, pods, roots, flowers, and bark, has been used in traditional medicine and cuisine. The leaves of *M. oleifera,* in particular, are consumed fresh, cooked, or dried into powder for long-term storage, reportedly without significant loss of their nutritional content (Fahey, 2005). Numerous studies have confirmed the health benefits of moringa leaves, which have demonstrated anti-inflammatory, anti-tumor, anti-ulcer, anti-atherosclerotic, and anticonvulsant activities (Chumark et al., 2008).

The scientific exploration of *M. oleifera* spans multiple disciplines, including nutrition, ethnobotany, analytical and phytochemistry, medicine, and anthropology (McBurney et al., 2004). The leaves are rich in essential vitamins and minerals, such as calcium, iron, potassium, and vitamins A, C, and E, along with a variety of phytochemicals that contribute to its therapeutic potential (Fahey, 2005; Anwar and Bhanger, 2003). They are traditionally used to treat malnutrition, especially in children and lactating mothers, and are known for their antioxidant, antimicrobial, antidiabetic, and anticancer properties (Kumar and Sharma, 2015; Gopalakrishnan and Chidambaram, 2018)

In addition to its medicinal uses, *M. oleifera* seeds serve as a natural coagulant for water purification, a method increasingly applied in rural and low-resource settings (Berger et al., 1984). The seeds also yield a high-quality oil, commonly referred to as Ben oil, known for its non-drying, oxidation-resistant characteristics. This oil is used in the production of cosmetics, hair care products, and lubricants, and even as a base for edible oils (Tsaknis et al., 1999). In culinary applications, *Moringa* seeds are consumed green, roasted, powdered, or infused into teas and stews (Gassenschmidt et al., 1995).

Given its nutrient density and bioactive compounds, *M. oleifera* is considered a sustainable solution for improving health and nutrition in many developing regions. This review presents

an overview of the nutritional, therapeutic, and prophylactic properties of M. oleifera. It highlights its applications in the prevention and treatment of chronic diseases, such as diabetes and cancer, and explores the potential for integrating *M. oleifera* into commercial food and pharmaceutical products. The review also considers the plant's cultural, agricultural, and industrial significance, reinforcing its status as a multipurpose resource for human well-being (Gopalakrishnan et al., 2016).

2. Botanical Description and Cultivation

M. oleifera Lam. is a fast-growing, deciduous tree from the Moringaceae family, native to the Indian subcontinent but now widely cultivated in tropical and subtropical regions worldwide. Known for its drought resistance and ability to thrive in arid conditions, *M. oleifera* grows up to 5 to 12 meters tall, with a straight, softwood trunk and a canopy shaped like an umbrella. The tree produces compound leaves that are rich in essential nutrients, and it is characterized by fragrant, cream-colored flowers that bloom year-round in favorable climates. These flowers develop into long, slender pods containing seeds, which are often referred to as "drumsticks" (Fahey, 2005).

The plant is adaptable to a wide range of soil types, thriving in sandy or loamy soils with a neutral to slightly acidic pH (6.3–7.0). It grows best in areas with annual rainfall ranging from 250 to 1,500 mm and temperatures between 25°C and 35°C. Moringa's deep taproot system allows it to access water from deeper soil layers, contributing to its ability to withstand periods of drought (Akinmoladun et al., 2020). It is propagated either by seeds or stem cuttings, with seed propagation being the most common method due to its high germination rate and ease of planting (Kumar and Gupta, 2017). In addition to its nutritional value, *M. oleifera* has become an important crop in areas with food insecurity due to its rapid growth cycle and high yield of edible parts, including leaves, seeds, and pods. It can be harvested multiple times a year, making it an invaluable resource in regions with limited access to water and fertile soil (Siddhuraju and Becker, 2003).

3. Nutritional Composition

M. oleifera is widely recognized for its exceptional nutritional profile. The leaves, seeds, flowers, and pods of the plant are rich in essential vitamins, minerals, and bioactive compounds, making it a highly nutritious addition to the diet. The leaves are especially prized for their high content of protein, essential amino acids, vitamins (A, C, and E), and minerals such as calcium, iron, and potassium. The leaves also contain significant amounts of carotenoids, which are precursors to vitamin A, and polyphenols with antioxidant properties (Fahey, 2005; Sreelatha and Padma, 2011).

The leaves of *M. oleifera* are considered a superior source of bioavailable protein and micronutrients compared to other vegetables, particularly in regions where malnutrition is prevalent. A study by Moyo et al. (2015) demonstrated that *Moringa* leaves contain about 6–9% protein by weight, which is higher than that of most conventional leafy vegetables. Furthermore, *M. oleifera* is one of the richest sources of calcium (up to 30 times higher than in milk), making it an excellent dietary supplement for bone health (Sharma et al., 2012).

The seeds of *M. oleifera* are also highly nutritious, containing significant amounts of lipids, including healthy unsaturated fatty acids. *Moringa* seed oil, also known as Ben oil, is non-drying, non-sticky, and resists rancidity, making it suitable for use in cosmetics and as a culinary oil (Tsaknis et al., 1999). In addition to the nutritional benefits, the seeds have medicinal properties, including antimicrobial and anti-inflammatory effects, and are used as a natural coagulant in water purification (Berger et al., 1984).

The pods of *M. oleifera* are another valuable edible part of the plant, often consumed in various culinary forms. They contain high levels of fiber, vitamins, and minerals. The nutritional

composition of the plant makes it an ideal functional food for addressing nutritional deficiencies, particularly in developing countries (Gernah et al., 2013).

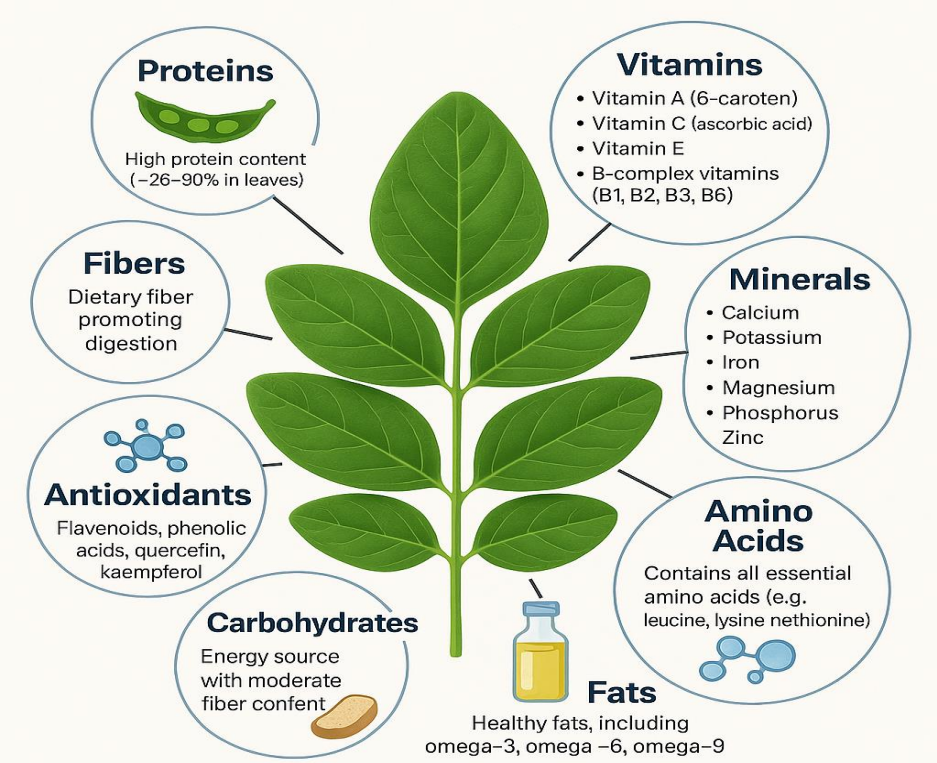


Figure 1. Major Nutritional Components of *Moringa oleifera.*

4. Biochemical Composition of *Moringa oleifera*

The proximate composition of *M. oleifera* leaves is presented in Table 1. The results presented by Anwar et al., 2007, highlight the high nutritional potential of the plant, especially regarding its protein, fiber, and mineral content.

Table 1. Proximate composition of *Moringa oleifera* leaf (g/100 g dry weight)

Parameter	Mean Value ± SD
Moisture	7.23 ± 0.12
Protein	25.30 ± 0.27
Lipid	5.75 ± 0.21
Ash	9.95 ± 0.12
Carbohydrates	29.80 ± 4.55
Dietary Fiber	24.97 ± 4.55

The low moisture content (7.23%) indicates that dried *Moringa* leaves are stable and less prone to microbial spoilage, making them suitable for long-term storage and industrial applications (Anwar et al., 2007). The protein content (25.30%) is particularly high for a leafy vegetable, surpassing that of many conventional greens such as spinach or kale. This positions *M. oleifera* as a valuable plant-based protein source, particularly in areas affected by malnutrition or food

insecurity (Moyo et al., 2011). Moreover, the leaf protein contains essential amino acids, including leucine, isoleucine, and valine, which are necessary for human health (Sánchez-Machado et al., 2010). Although lipids are present in moderate amounts (5.75%), studies show that *Moringa* leaf fat is rich in unsaturated fatty acids, such as oleic and linoleic acid, which have been associated with anti-inflammatory and cardioprotective properties (Mbikay, 2012).
The ash content (9.95%) reflects a high level of mineral elements. *M. oleifera* leaves are known to contain calcium, potassium, magnesium, iron, and zinc (Gopalakrishnan et al., 2016), all of which play vital roles in bone health, enzymatic activity, oxygen transport, and immune function. In addition, the leaves exhibit considerable amounts of carbohydrates (29.80%) and dietary fiber (24.97%). The high fiber content can aid digestive health, improve bowel movements, and help regulate blood sugar and cholesterol levels. Furthermore, dietary fiber promotes satiety, which is beneficial for weight management (Fahey, 2005).
Overall, the proximate composition of *M. oleifera* leaves confirms their exceptional nutritional value and supports their potential inclusion in the formulation of functional foods, dietary supplements, and malnutrition intervention programs.

5.Safety and Pharmacological Evidence

5.1 Safety Studies

To date, no adverse effects have been reported in any human studies involving *M. oleifera*. This safety profile is consistent with its widespread traditional use across many cultures, where various parts of the plant, particularly the leaves, have been consumed both as food and in medicinal preparations for generations (Fahey, 2005). Numerous animal studies have also been conducted to assess the potential toxicity of *Moringa* leaf extracts, seeds, and root preparations. The results consistently indicate a low risk of toxicity, even at relatively high doses (Stohs and Hartman, 2015). These findings provide strong support for the continued exploration of *M. oleifera* in therapeutic and nutritional applications.

5.2. Human Studies and Medicinal Importance of *Moringa oleifera*

Although clinical trials in humans remain limited, existing data support the potential therapeutic value of *M. oleifera*, particularly in the management of metabolic disorders such as type 2 diabetes and dyslipidemia. In a study conducted by Kumari et al. (2010), 46 type 2 diabetic patients were administered 8 g of powdered *M. oleifera* leaf per day in tablet form for 40 days. The results were promising: fasting and postprandial blood glucose levels decreased by 28% and 26%, respectively, in the treatment group compared to baseline values (Kumari et al., 2010). In addition, notable reductions were observed in total cholesterol (14%), triglycerides (14%), LDL-cholesterol (29%), and VLDL-cholesterol (15%) relative to the control group (Kumari et al., 2010). Importantly, no adverse effects were reported throughout the duration of the study, reinforcing the safety of oral administration of whole leaf powder (Kumari et al., 2010). While none of the existing clinical trials have involved the use of concentrated leaf extracts, the data collectively suggest that *M. oleifera* possesses anti-hyperglycemic, anti-dyslipidemic, and antioxidant properties that may be clinically relevant (Anwar and Bhanger, 2003; Fahey, 2005).
Often referred to as the "natural nutrition of the tropics," *Moringa oleifera* has been widely recognized for its broad range of medicinal applications. Almost every part of the tree, including leaves, seeds, bark, roots, and pods, has been used in traditional medicine systems such as Ayurveda, Unani, and African folk medicine. A summary of its documented pharmacological properties is presented in Table 2.

Table 2. Medicinal properties associated with *Moringa oleifera*.

Pharmacological Activity	Reference
Diuretic	Caceres et al., 1992
Cholesterol-lowering	Mehta et al., 2003
Antihypertensive	Faizi et al., 1994a; 1995
Antispasmodic	Caceres et al., 1992
Antiulcer	Dangi et al., 2002
Hepatoprotective	Gilani et al., 1997
Antitumor and anticancer	Bharali et al., 2003
Antibacterial and antifungal	Eilert et al., 1981
Antidiabetic	Coppin, 2008
Wound healing	Majhi, 2013
Antipyretic	Coppin, 2008
Analgesic	VijayKumar et al., 2012
Anti-inflammatory	Sengul et al., 2009
Anti-asthmatic	Farooq et al., 2012
Antioxidant	Compaore et al., 2011
Antiurolithiatic	Debey et al., 2013

These diverse pharmacological effects are attributed to the wide array of bioactive compounds in *Moringa*, including flavonoids, glucosinolates, phenolic acids, alkaloids, and isothiocyanates (Compaore et al., 2011).

5.4. Health Benefits of *Moringa oleifera*

Beyond its nutritional value, *M. oleifera* exhibits pharmacological activities that may help prevent or manage several chronic diseases. Experimental studies have demonstrated that bioactive compounds extracted from *Moringa* can inhibit the progression of certain cancers, including lung cancer (Xie et al., 2020) and breast carcinoma (Adebayo et al., 2018). Additional research suggests its potential role in the treatment or prevention of diabetes (Tuorkey, 2016), periodontitis (Wang et al., 2021), and acute pancreatitis, among others. The therapeutic potential of *Moringa* is largely attributed to its antioxidant, anti-inflammatory, antibacterial, and antiviral properties. Its antioxidant compounds help neutralize reactive oxygen species, reducing oxidative stress, a key factor in the pathogenesis of chronic diseases such as cancer and diabetes (Siddhuraju and Becker, 2003). Meanwhile, its anti-inflammatory and immunomodulatory actions contribute to its efficacy in managing inflammatory conditions, including asthma and arthritis (Farooq et al., 2012).

Conclusion

This review highlights the medicinal and bioactive properties of *M. oleifera,* with a particular emphasis on its antioxidant potential, as well as its content of phenolic compounds, alkaloids, and proteins. The current body of literature demonstrates that *M. oleifera* possesses significant therapeutic potential, notably due to its anti-inflammatory, antihyperglycemic, and cholesterol-lowering effects. Its wide spectrum of pharmacological activities supports its traditional use and validates its role as a functional food and natural remedy. However, despite these promising findings, further well-designed studies are needed to confirm its efficacy and safety, particularly

in human populations. Future research should focus on identifying active compounds, optimizing extraction methods, and conducting large-scale clinical trials to better understand the mechanisms behind its health-promoting effects. Addressing these gaps will be essential to fully integrate *M. oleifera* into evidence-based therapeutic practices.

Author Contribution Statement

Ibtissem BENGHALEM: writing the original manuscript; **Zoubida MAMI-SOUALEM, Radjaa Kaouthar Meziane,** and **Mansouria Souria Bendeddouche:** contributing to the writing and correction of this work.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Adebayo, I. A., et al. (2018). Cytotoxic and antioxidant effects of *Moringa oleifera* leaf extract on human breast cancer cells. *BMC Complementary and Alternative Medicine*, 18(1), 1–9.

Akinmoladun, F. O., Akinmoladun, A. T., & Onajobi, F. D. (2020). The Moringa oleifera tree: A potential source of bioactive compounds for the development of functional foods. *Journal of Food Science and Technology*, 57(8), 2903–2915. https://doi.org/10.1007/s11483-020-02962-x

Anwar, F., Latif, S., Ashraf, M., & Gilani, A. H. (2007). *Moringa oleifera*: A food plant with multiple medicinal uses. *Phytotherapy Research*, 21(1), 17–25. https://doi.org/10.1002/ptr.2023

Berger, A., Witte, T., & Moser, M. (1984). Use of *Moringa oleifera* seeds as a coagulant in water purification. *Water Research*, 18(7), 1001–1005. https://doi.org/10.1016/0043-1354(84)90212-0

Bharali, R., et al. (2003). Chemomodulatory effect of *Moringa oleifera* on hepatic carcinogen metabolizing enzymes. *Journal of Experimental Therapeutics and Oncology*, 3(4), 249–259.

Bose, S., & Panda, S. K. (2023). *Moringa oleifera*: An Updated Comprehensive Review of Its Nutritional, Phytochemical, and Pharmacological Properties. *Pharmaceuticals*, 16(1), 142. https://doi.org/10.3390/ph16010142

Caceres, A., et al. (1992). Pharmacologic properties of *Moringa oleifera*. 1: Preliminary screening for antimicrobial activity. *Journal of Ethnopharmacology*, 36(3), 233–237.

Chumark, P., Tewtrakul, S., & Kanjanapothi, D. (2008). The in vitro and ex vivo antioxidant properties, hypolipidemic and antiatherosclerotic activities of Moringa oleifera Lam. leaves. *Journal of Ethnopharmacology*, 116(3), 439-446. https://doi.org/10.1016/j.jep.2007.12.011

Coppin, J. P. (2008). A review of the nutritional and medicinal properties of Moringa oleifera. *Phytotherapy Research*, 22, 17–25.

Dangi, S. Y., et al. (2002). Evaluation of antiulcer activity of *Moringa oleifera*. *Phytomedicine*, 9(6), 487–493.

Debey, P., et al. (2013). Antiurolithiatic effect of *Moringa oleifera* in albino rats. *International Journal of Pharmaceutical Sciences*, 5(3), 536–540.

Eilert, U., et al. (1981). The antibiotic principle of *Moringa oleifera*. *Planta Medica*, 42(1), 55–61.

Fahey, J. W. (2005). *Moringa oleifera*: A review of the medical evidence for its nutritional, therapeutic, and prophylactic properties. Part 1. *Trees for Life Journal*, 1(5), 1–15.

Farooq, A., et al. (2012). Medicinal properties of *Moringa oleifera*: An overview. *Pakistan Journal of Botany*, 44(1), 1–10.

Gassenschmidt, U., et al. (1995). The antibacterial and flocculant properties of Moringa oleifera seeds. *Water Research*, 29(2), 715-720. https://doi.org/10.1016/0043-1354(94)00292-8

Gernah, D. I., Ozumba, A. U., & Ezeani, C. N. (2013). Moringa oleifera pods: A potential source of dietary fiber and micronutrients. *American Journal of Food Science and Technology*, 1(1), 1–7. https://doi.org/10.12691/ajfst-1-1-1

Gilani, A. H., et al. (1997). Antispasmodic and blood pressure-lowering effects of *Moringa oleifera* root extracts. *Phytotherapy Research*, 11(6), 463–467.

Gopalakrishnan, L., Doriya, K., & Kumar, D. S. (2016). *Moringa oleifera*: A review on nutritive importance and its medicinal application. *Food Science and Human Wellness*, 5(2), 49–56. https://doi.org/10.1016/j.fshw.2016.04.001

Kumar, A., & Gupta, S. (2017). Moringa oleifera: A potential tree of life for global health. *Journal of Pharmacognosy and Phytochemistry*, 6(5), 100–105.

Kumari, D. J. (2010). Hypoglycemic effect of *Moringa oleifera* leaf powder in diabetic patients. *International Journal of Health Sciences*, 4(1), 14–18.

Mbikay, M. (2012). Therapeutic potential of *Moringa oleifera* leaves in chronic hyperglycemia and dyslipidemia: A review. *Frontiers in Pharmacology*, 3, 24. https://doi.org/10.3389/fphar.2012.00024

McBurney, M. I., & MacDonald, R. S. (2004). *Moringa oleifera*: A plant with therapeutic potential. *Journal of Nutritional Biochemistry*, 15(7), 419-429. https://doi.org/10.1016/j.jnutbio.2004.02.004

Mehta, K., et al. (2003). Cardioprotective effect of *Moringa oleifera* in myocardial infarction. *Journal of Ethnopharmacology*, 86(2–3), 215–221.

Moyo, B., Masika, P. J., Hugo, A., & Muchenje, V. (2011). Nutritional characterization of Moringa (Moringa oleifera Lam.) leaves. *African Journal of Biotechnology*, 10(60), 12925–12933. https://doi.org/10.5897/AJB11.1125

Moyo, B., Masika, P. J., Hugo, A., & Muchenje, V. (2015). Nutritional characterization of *Moringa oleifera* leaves and pods: A review. *Food Research International*, 65, 39–50. https://doi.org/10.1016/j.foodres.2014.09.029

Sánchez-Machado, D. I., Núñez-Gastélum, J. A., Reyes-Moreno, C., Ramírez-Wong, B., & López-Cervantes, J. (2010). Nutritional quality of edible parts of *Moringa oleifera*. *Food Analytical Methods*, 3(3), 175–180. https://doi.org/10.1007/s12161-010-9130-2

Sengul, M., et al. (2009). Antioxidant and anti-inflammatory activities of *Moringa oleifera*. *International Journal of Food Sciences and Nutrition*, 60(1), 71–81.

Sharma, S. K., & Bhowmik, D. (2012). *Moringa oleifera*: A review on its medicinal properties and application. *International Journal of Pharmacognosy*, 49(4), 257–264.

Siddhuraju, P., & Becker, K. (2003). Antioxidant properties of various solvent extracts of *Moringa oleifera* leaves. *Food Chemistry*, 83(2), 224–235. https://doi.org/10.1016/S0308-8146(03)00097-5

Stohs, S. J., & Hartman, M. J. (2015). Review of the safety and efficacy of *Moringa oleifera*. *Phytotherapy Research*, 29(6), 796–804.

Sreelatha, S., & Padma, P. R. (2011). Antioxidant and anticancer activity of *Moringa oleifera* leaves. *Phytomedicine,* 18(3), 141–146. https://doi.org/10.1016/j.phymed.2010.07.016

Tsaknis, J., et al. (1999). *Moringa* oil (Ben oil) as an edible oil. *Journal of the American Oil Chemists' Society*, 76(12), 1333–1335. https://doi.org/10.1007/s11746-999-0177-3

Tuorkey, M. J. (2016). Therapeutic role of *Moringa oleifera* in diabetes mellitus. *Asian Pacific Journal of Tropical Medicine*, 9(9), 824–831.

VijayKumar, M., et al. (2012). Analgesic activity of *Moringa oleifera* leaf extracts. *Pharmacognosy Research*, 4(3), 170–172.

Wang, F., et al. (2021). *Moringa oleifera* leaf extract promotes periodontal healing. *Journal of Oral Science*, 63(1), 123–129.

Xie, J., et al. (2020). Anti-cancer effects of *Moringa oleifera* leaf extract in lung cancer cells. *Frontiers in Pharmacology*, 11, 564404