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Nutritional food, Phytochemical, Pharmacological and Medicinal Benefits of *Moringa oleifera* Lam.

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ABSTRACT

Moringa oleifera, commonly known as the drumstick tree, is a fast-growing, perennial plant that can reach heights of 10-12 m. It is highly adaptable and thrives in diverse climates, from rainforest zones to dry, arid regions with minimal rainfall. The tree can be propagated through seeds or stem cuttings. Often called the "Miracle tree", *Moringa oleifera* is renowned for its exceptional nutritional value, which plays a crucial role in human health. The tree's chemical composition varies across its different parts and is influenced by environmental conditions, cultivar, and geographical location. *Moringa oleifera* is versatile, serving multiple purposes such as food for humans and livestock, improving soil fertility, producing biogas, and being used in water purification, gum, and pulp production. Various parts of the tree-including the leaves, roots, seeds, bark, flowers, fruit, and immature pods-offer numerous medicinal benefits. These include promoting heart health, reducing inflammation, treating fevers, preventing tumors, controlling diabetes, lowering cholesterol, and offering antibacterial, antifungal, and antioxidant properties. These health benefits have made *Moringa* a key component of traditional medicine, especially in South Asia. Additionally, *Moringa oleifera* demonstrates significant morphological and genetic diversity, making it a valuable resource for conservation efforts and the development of superior varieties. This article delves into the many uses and benefits of *Moringa oleifera* across various sectors.

KEYWORDS

Food products, *Moringa oleifera,* food benefits, medicinal, pharmacological benefits

INTRODUCTION

Moringa oleifera, a member of the Moringa genus, is the sole species in the Moringaceae family. This tree, which is one of 14 species in the family, is native to various regions, including Africa, Arabia, India, Southeast Asia, South America, and the Pacific and Caribbean Islands[1]. Often referred to as one of the versatile and valuable trees in the world, *Moringa oleifera* can be used in numerous ways, including for food, medicine, and industrial purposes[2]. It has earned the nickname "Mother's best friend" for its ability to promote milk production in lactating women[3], and is commonly regarded as a "Natural gift of nature". Due to its environmental benefits and adaptability to diverse climates, particularly in tropical and subtropical regions, *Moringa oleifera* is known by several common names. These include the Horseradish tree, Drumstick tree, Ben oil tree, Miracle tree, and "Mother's best friend"[1]. In different languages and regions, it is called "Okwe Oyibo" in Igbo, "Zogale" in Hausa, and "Ewe Ile" in Yoruba. Globally, it is also

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known as "Nuggekai" in Canada, "Sonjna" in Marathi, "Murungai" in Tamil, "Mashinga sanga" in Malayalam, and "Muringa" in Konkani[4]. Additionally, other popular names for Moringa include "resedá", "Árbol de rábano", horseradish tree, drumstick tree, "Ângela", "árbol de los espárragos", white-lily, and "quiabo de quina"[5].

Moringa thrives in a wide range of soils, particularly in well-drained, sandy or loamy soils with a slightly alkaline pH. It prospers in both humid tropical climates and hot, arid regions, and is notably resilient in poor soils and drought-prone conditions[6]. In many developing countries, herbal medicine is a cornerstone of healthcare, with many people relying on natural remedies often in the form of herbal concoctions for the prevention and treatment of various health issues. Despite the availability of modern pharmaceuticals, herbal remedies remain deeply ingrained in the cultural and historical fabric of these communities[7]. While Moringa's potential is underutilized in some rural areas due to limited awareness, it remains a valuable resource in traditional medicine. This review aims to shed light on the numerous health benefits of Moringa, also known as the "Mother's Best Friend" or the "Miracle Tree."

NUTRITIONAL FOOD BENEFITS

Moringa oleifera is increasingly recognized as a highly valuable food source, not only for human nutrition but also for improving the nutritional quality of animal diets. Several studies have demonstrated its beneficial contributions to balanced diets, supporting both human health and livestock development[8]. Moringa is often referred to as a "superfood" due to its rich nutrient profile and the diverse health benefits it offers. Every part of the Moringa tree, whether it's the leaves, pods, seeds, or flowers contains a range of vital nutrients and beneficial compounds.

The leaves of *Moringa oleifera* are particularly rich in essential minerals. They are excellent sources of calcium, potassium, magnesium, iron, zinc, and copper, which are crucial for various bodily functions[9]. The tree also provides an array of vitamins, including vitamin A (in the form of beta-carotene), B vitamins (such as folic acid, pyridoxine, and nicotinic acid), and vitamins C, D, and E, which are important for immune function, skin health, and overall well-being[10]. Additionally, Moringa leaves are rich in a variety of phytochemicals-including tannins, sterols, terpenoids, flavonoids, saponins, anthraquinones, alkaloids, and reducing sugars-which contribute to their diverse therapeutic effects, including anti-cancer properties. Notably, glucosinolates, isothiocyanates, glycosides, and glycerol-1-9-octadecanoate are among the compounds found in Moringa that are thought to have anti-cancer effects[11]. Moringa leaves have a relatively low calorific value, making them an excellent dietary addition for individuals aiming to manage their weight or for those dealing with obesity. The tree's pods are fibrous and are widely used in treating digestive issues. They are also believed to have potential cancer-preventative properties, particularly for colon cancer[12]. Research shows that Moringa's immature pods contain a high percentage of Fibre (approximately 46.78%) and protein (approximately 20.66%). These pods are also rich in amino acids, with the protein content of the pods, leaves, and flowers varying at 30, 44, and 31% respectively. The pods and flowers share a similar fatty acid profile, containing palmitic, linolenic, linoleic, and oleic acids, all of which contribute to the overall nutritional quality of the tree[13]. One of the standout features of Moringa is its high mineral content. For instance, calcium, which is essential for bone health and growth, is found in Moringa leaves in higher quantities compared to common sources like milk. While 8 ounces of milk provides 300-400 mg of calcium, Moringa leaves can provide as much as 1,000 mg, and Moringa powder can give over 4,000 mg. Similarly, Moringa powder is a natural alternative to iron supplements, with 28 mg of iron per 100 g serving, significantly more than beef (which provides only 2 mg per 100 g) and even spinach[14]. Adequate zinc intake is essential for the proper development of sperm cells and the synthesis of DNA and RNA. Moringa leaves contain between 25.5 and 31.03 mg of zinc per kg, which corresponds to the daily zinc requirement for an average adult[15]. Additionally, Polyunsaturated Fatty Acids (PUFAs), such as linoleic acid, linolenic acid, and oleic acid, present in Moringa seeds, have cholesterol-lowering properties. Moringa seed oil contains up to 76% PUFAs, making it a suitable

substitute for olive oil in various culinary applications[16]. Moringa is not only rich in nutrients but also contributes to improving the nutritional quality of food products. The foliage, flowers, green pods, seeds, and seed oil of Moringa contain low levels of saturated fatty acids and high amounts of monounsaturated and polyunsaturated fatty acids. These features make Moringa an excellent candidate for value-added food products[17]. Furthermore, Moringa seeds are a promising resource for both food and non-food applications, thanks to their high content of monounsaturated fatty acids, tocopherols, and proteins rich in sulfur-containing amino acids[18].

It is important to note that the nutrient composition of Moringa can vary depending on environmental factors such as location and climate. Studies have shown that during the hot-wet season, Moringa leaves tend to have higher levels of vitamin A, while vitamin C and iron are more abundant during the cool-dry season[19]. The nutritional content of Moringa is therefore influenced by the climate, location, and other environmental conditions in which it is grown[20]. *Moringa oleifera* has attracted significant attention for its role as a nutritional powerhouse, often referred to as the "natural nutrition of the tropics". In many countries across Asia, Africa, and the Pacific Islands, including India, Pakistan, the Philippines, Hawaii, and parts of Africa, various parts of the Moringa tree such as the leaves, fruit, flowers, and immature pods are used as highly nutritious vegetables[21]. Moringa leaves are especially valued for their high content of β-carotene, protein, vitamin C, calcium, and potassium. In addition, they serve as a rich source of natural antioxidants that help extend the shelf-life of fat-containing foods. These antioxidants include ascorbic acid, flavonoids, phenolics, and carotenoids[22]. A recent study conducted in Zambia examined the impact of dried Moringa leaf powder on the nutritional status and body composition of malnourished children aged 4 to 18 years. The results demonstrated the potential of Moringa as a therapeutic food for combating malnutrition[23]. Furthermore, studies on the incorporation of Moringa leaf powder into cakes have shown that increasing amounts of Moringa in the recipe enhances the cakes' moisture, protein, fiber, and ash content, while reducing their total fat and carbohydrate levels[24]. Additionally, dried Moringa root powder, mixed with acetic acid, is consumed as a condiment in certain cultures[25]. Hence, *Moringa oleifera* is a versatile and highly nutritious tree that provides a wide range of health benefits. Its various parts, including the leaves, flowers, pods, and seeds, offer an abundant supply of essential nutrients, including vitamins, minerals, proteins, and antioxidants. Moringa's ability to improve the nutritional quality of food and its potential to address issues like malnutrition and anemia make it an invaluable resource for sustainable nutrition, particularly in developing countries.

PHYTOCHEMICAL BENEFITS

Moringa oleifera is widely recognized for its rich content of bioactive phytochemicals, which contribute significantly to its numerous health-promoting properties[26]. The plant is particularly abundant in compounds containing simple sugars such as rhamnose, as well as a distinctive group of compounds known as glucosinolates and isothiocyanates[27]. These substances have been extensively studied for their hypotensive, anticancer (chemopreventive), and antibacterial activities. Key bioactive compounds identified in *M. oleifera* include:

- 4-(4'-O-acetyl-α-L-rhamnopyranosyloxy)benzyl isothiocyanate
- 4-(α-L-rhamnopyranosyloxy)benzyl isothiocyanate
- Niazimicin[28]
- Pterygospermin[29]
- Benzyl isothiocyanate[30]
- 4-(α-L-rhamnopyranosyloxy)benzyl glucosinolate

These compounds are largely responsible for the therapeutic potential attributed to *Moringa oleifera*, particularly in lowering blood pressure, combating bacterial infections, and offering protection against certain types of cancers. Another prominent class of phytochemicals in *Moringa oleifera* includes flavonoids and phenolic acids, collectively known as phenolic compounds. Among these:

- Quercetin and kaempferol (in their 3-O-glycoside forms) are the dominant flavonols found in the leaves
- Quercetin, in particular, is a powerful antioxidant with multiple therapeutic effects. It is commonly present in the form of quercetin-3-O-β-D-glucoside, also known as isoquercitrin or isotrifolin, and has demonstrated antidyslipidemic, hypotensive, and antidiabetic effects in studies involving obese Zucker rats[31]. Another important compound in *Moringa oleifera* is chlorogenic acid, which plays a significant role in glucose metabolism. Research in animal models has shown that this compound
- Inhibits glucose-6-phosphate translocase in the liver
- Reduces hepatic gluconeogenesis and glycogenolysis[32]
- Contributes to improved glucose control

The stem bark of *M. oleifera* contains alkaloids such as:

- Moringine and moringinine, which are associated with improved glucose tolerance[33]
- Other compounds include vanillin, β-sitostenone, 4-hydroxymellin, and octacosanoic acid

In addition, the leaves are a source of:

- Niaziminin, believed to contribute to its hypotensive activity
- β-sitosterol, a phytosterol that may help reduce intestinal cholesterol absorption[34]
- Carotenoids (such as β-carotene), provitamin A, and other antioxidants

More than 40 natural antioxidant compounds have been identified in *Moringa oleifera*[35]. These include:

- Phenolic compounds
- Flavonoids
- Tannins
- Alkaloids
- Saponins
- Glucosides[36]

Such diversity makes *Moringa* leaves a valuable source of natural antioxidants, which enhance their reputation as a nutraceutical and functional food ingredient[37]

Despite its benefits, *Moringa oleifera* also contains antinutrients compounds that may reduce the bioavailability of nutrients. Of note is: Spirochin, an alkaloid identified particularly in the seeds, which is potentially neurotoxic at high doses[38]. However, it also exhibits antibacterial activity at lower, non-toxic levels[39]. Importantly, the levels of such antinutritional compounds are typically low in dietary use, and toxic effects require ingestion in significantly large quantities. Thus, *Moringa oleifera* is a highly nutritious and medicinally valuable plant, rich in a wide spectrum of bioactive compounds. From isothiocyanates and flavonoids to chlorogenic acid and alkaloids, its diverse phytochemical profile supports its traditional and modern uses in managing conditions such as hypertension, diabetes, infections, and oxidative stress. While some antinutrients are present, they pose minimal risk when the plant is consumed in reasonable amounts, reinforcing *Moringa's* status as a promising functional food and natural remedy.

PHARMACOLOGICAL AND MEDICINAL BENEFITS

Moringa oleifera, commonly known as Moringa, is often referred to as a "panacea" due to its wide range of medicinal properties. It has been traditionally used for centuries in both Indian and African herbal medicine, and modern research supports its effectiveness in treating over 300 different diseases. Various parts of the Moringa plant roots, leaves, flowers, gum, and seeds have been found to possess significant therapeutic properties, making it a valuable natural remedy. Among its many benefits, Moringa has been shown to possess diuretic, anti-inflammatory, antioxidant, and anti-cancer activities.

Research has shown that Moringa roots, leaves, flowers, and the aqueous infusion of its seeds exhibit diuretic effects, which could complement its overall ability to lower blood pressure[40]. This diuretic activity contributes to its role in managing hypertension, further enhancing Moringa's reputation as a natural remedy for various health conditions. Several studies have highlighted Moringa's potential as an anti-diabetic agent. In particular, research has shown that Moringa can help manage both Type 1 and Type 2 diabetes. Aqueous extracts of *Moringa oleifera* effectively treated streptozotocin (STZ)-induced Type 1 diabetes and insulin-resistant Type 2 diabetes in rats[41]. Moringa seed powder to STZ-induced diabetic rats led to a significant decrease in fasting blood glucose levels[42]. The therapeutic effects of Moringa in diabetes are largely attributed to the presence of bioactive compounds such as flavonoids and phenolics. These compounds possess antioxidant properties that help scavenge Reactive Oxygen Species (ROS) generated by mitochondria. This action likely protects insulin-producing beta cells in the pancreas, preventing hyperglycemia and contributing to better blood sugar control.

Moringa's antioxidant properties also make it a promising anti-cancer agent. Studies have indicated that Moringa exhibits a selective ROS production mechanism that targets only cancer cells, which enhances its potential as an effective cancer treatment. Moringa extracts increased the expression of glutathione-S-transferase, an enzyme that inhibits the expression of pro-oxidant molecules and plays a key role in cellular defense against oxidative stress[43].

Moringa has also shown significant neuroprotective potential. *Cerebral ischemia*, a condition caused by the obstruction of blood flow to the brain, results in reperfusion injury and the generation of harmful ROS. Moringa's antioxidant properties can mitigate this damage by reducing the levels of ROS, thus protecting brain cells from oxidative stress and damage[44]. Additionally, Moringa has been shown to promote spatial memory and improve cognitive function, making it a valuable remedy for conditions such as dementia. Moringa leaf extracts reduced acetylcholinesterase activity, which in turn improved cholinergic function and memory retention[45]. Moringa has demonstrated beneficial effects on gastrointestinal health. A study revealed that Moringa extracts significantly reduced gastric acidity, with a decrease in acidity levels of 86.15 and 85.13% at doses of 500 and 350 mg, respectively[46]. This suggests that Moringa can be used effectively as an anti-ulcer agent to treat conditions like peptic ulcers and acidity. Moringa's antimicrobial properties have been well-documented, making it an effective natural agent against a range of microbial infections. Moringa extracts exhibit antibacterial activity against harmful bacteria such as *Bacillus subtilis*, *Staphylococcus aureus*, and *Vibrio cholera*[47]. The antibacterial effects of Moringa seeds have been attributed to the presence of compounds like pterygospermin, moringine, and benzylisothiocyanate[48]. These properties make Moringa a promising natural alternative for treating infections. In traditional folk medicine, various parts of the Moringa plant are used to treat a variety of conditions. The roots, leaves, and flowers are commonly used for ailments such as ascites, rheumatism, venomous bites, and as cardiac and circulatory stimulants. The oil extracted from Moringa is applied externally to treat skin diseases, while the root bark is used as a rubefacient and vesicant. Moringa's therapeutic potential extends to other areas, such as reducing symptoms of high cough, influenza, and viral infections[49]. Moringa is not only beneficial for specific diseases but also supports overall health. It has been found to:

- Support a healthy cardiovascular system
- Promote normal blood glucose levels
- Neutralize free radicals that contribute to cancer development
- Provide anti-inflammatory effects, which support the body's natural defense mechanisms
- Improve blood health, particularly in cases of anemia
- Strengthen the immune system and promote overall vitality[50]

The plant is also recognized for its benefits in improving eyesight, mental alertness, and bone strength. It holds potential as a treatment for malnutrition, general weakness, menopausal symptoms, depression, and osteoporosis. Hence, *Moringa oleifera* is a versatile plant with an impressive array of health benefits.

Its various bioactive compounds, including flavonoids, phenolics, and antioxidants, contribute to its effectiveness in managing chronic conditions such as diabetes, cancer, and neurodegenerative diseases. Furthermore, its antimicrobial, anti-inflammatory, and gastroprotective properties make it a valuable resource in traditional and modern medicine alike. As research continues to uncover the full spectrum of Moringa's therapeutic potential, it stands as a testament to the power of natural remedies in promoting human health and well-being.

CONCLUSION

The drumstick plant, scientifically known as *Moringa oleifera*, is often referred to as a "Miracle plant" due to its numerous untapped benefits, especially in food-related applications. It holds significant potential for agroforestry, owing to its rapid growth, ease of cultivation, and the wide range of valuable products it offers. Moringa provides both direct and indirect benefits to people and their livestock in various ways. Encouraging families to grow Moringa in their home gardens could enhance its widespread use, earning it the title of a "Family companion." Its diverse applications in food, medicine, and pharmaceuticals make it an exciting area for further research. More studies are needed to explore the different parts of the plant and their potential to support a more natural, sustainable way of living. Rather than relying on food aid from wealthier nations, poorer countries could boost their food security by focusing on cultivating and utilizing Moringa. Additionally, there is limited scientific research on how Moringa can address key challenges like climate change and food insecurity-issues that warrant greater attention and exploration.

SIGNIFICANCE STATEMENT

The article underscores the vast potential of *Moringa oleifera*, portraying it as a "Family companion" for its diverse uses in nutrition, medicine, and environmental sustainability. Promoting its cultivation in home gardens, especially in developing countries, could enhance self-sufficiency and lessen reliance on foreign food aid. Noted for its rich food, phytochemical, and nutritional profile, and medicinal value-stemming from its high content of essential nutrients and bioactive compounds - Moringa also offers environmental benefits, such as water purification through its seeds. Its considerable morphological and genetic diversity makes it a prime candidate for conservation and breeding programs. Despite its many advantages and a lack of reported adverse effects, research on Moringa remains limited, particularly in exploring its potential to combat global challenges like climate change and food insecurity.

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