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DISTRIBUTION, CHARACTERISTICS, NUTRITIONAL VALUES, COMMERCIALIZATION OPPORTUNITIES AND CONSERVATION STATUS OF *Moringa Oleifera*: A REVIEW

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Abstract:

This paper is a review of *Moringa oleifera (M. oleifera)* based on its distribution, characteristics, nutritional values, commercialization opportunities, and conservation status. This unique species was historically found in India and is well-known due to its benefits traditionally in pharmaceuticals. Extracts and isolates from *M. oleifera* have demonstrated effectiveness against diabetes, cancer, hypertension, pain, infertility, and infections in preclinical research. Recently, the commercialization of *M. oleifera* has been widely accepted by other nations which raise the demand domestically and internationally. Thus, it is essential to implement a systematic harvesting approach even though this species is currently listed as 'Least Concern'.

Keywords:

Commercialization, Conservation, Distribution, Moringa Oleifera, Nutrient

Introduction

Moringa oleifera (M. oleifera), also referred to as the "drumstick tree" or the "miracle tree," is a unique plant with a long and varied history across several biological habitats. This versatile tropical tree, which falls within the *Moringaceae* family, has attracted the interest of scientists, health enthusiasts, and conservationists. The production of this plant has had a rapid increase in Asia and Africa, mostly due to its crucial significance in many industrial uses, agriculture, and animal nutrition (Agoyi et al., 2014). To fully understand the importance of *M. oleifera*, it is crucial to explore its historical origins in Northwestern India, as this area is where it was first established (Singh et al., 2022). *M. oleifera*, intertwined with the histories of various societies, has had lasting impacts on ancient manuscripts, highlighting its traditional uses (Abd El-Hack et al., 2022). The leaves, pods, and seeds of this plant were highly regarded by ancient civilizations due to their exceptional nutritional content and were widely used in cooking as well as for medicinal purposes (Agoyi et al., 2014; Rockwood et al., 2013).

Furthermore, the "miracle tree" has been incorporated into the traditional medicine of various continents and civilizations because of its extraordinary botanical characteristics and its capacity to flourish in demanding environmental circumstances (Karmakar et al., 2024). *M. oleifera* is renowned for its abundance of vital phytochemicals found in its leaves, pods, and seeds. It offers remarkable levels of nutrients, including seven times the amount of vitamin C compared to oranges, ten times the amount of vitamin A compared to carrots, seventeen times the amount of calcium compared to milk, nine times the amount of protein compared to yoghurt, fifteen times the amount of potassium compared to bananas, and twenty-five times the amount of iron compared to spinach (Rockwood et al., 2013).

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This species has been the subject of several investigations throughout medicine, pharmacy, health, food science, and innovation (Abdelazim et al., 2024; Bangar et al., 2024; Barzan et al., 2024; Dwi Nanda, 2024; Elghandour et al., 2023; Husain et al., 2023). This demonstrates the capacity of this species to be further emphasised to maximise its potential (Li et al., 2024; Pareek et al., 2023; Segwatibe et al., 2023; Seminarwati et al., 2024; Zhang et al., 2024).

Despite the plant's significant medical applications, further research is required to elucidate and investigate the specifics of its separated components exhibiting synergistic effects (Bangar et al., 2024). Currently, there is still not enough information and evidence on the distribution, characteristics, nutritional values, commercialization opportunities and conservation status of *M. oleifera* (Abdelazim et al., 2024). This review seeks to elucidate the recent potential of M. oleifera across many applications explored by researchers in ecology, food science, and economics.

Methodology

The data collection for this manuscript entailed the methodical extraction of information from electronic databases, namely Google Scholar (https://scholar.google.com/), PubMed (https://pubmed.ncbi.nlm.nih.gov/), Scopus (https://www.scopus.com/), and ResearchGate (https://www.researchgate.net) (Mahaveerchand & Abdul Salam, 2024). The search queries utilized in these databases incorporated keywords such as *'Moringa oleifera*,' 'distribution of *M. oleifera*,' 'health benefits of *M. oleifera*,' 'medical properties of M. oleifera,' 'ecology of *M. oleifera*,' 'commercialization of *M. oleifera*,' 'phytoremediation in *M. oleifera*,' and 'Conservation status of *M. oleifera*.'

Findings

Distribution of *M. oleifera*

M. oleifera is native to the western and sub- Himalayan, India, Pakistan, Asia Minor, Africa, and Arabia. But it is now distributed in the Philippines, Cambodia, Central America, North and South America, the Caribbean Islands, and more. For a variety of purposes, it is now cultivated in the whole tropical and subtropical regions of the world (Thapa et al., 2019).

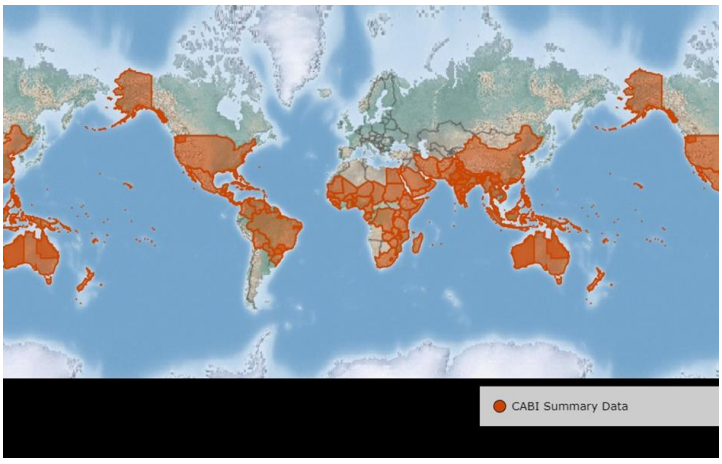

Figure 1: The Topographical Distribution of *M. oleifera* in The World. The Image of the World Map was Obtained from Vélez-Gavilán (2022)

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Based on the figure above, the distribution of *M. oleifera* in the world is outlined. This species is thought to originate from the northern India (Vélez-Gavilán, 2022). According to studies by Olson (2017), *M. oleifera* is only found in the wild in the hilly lowlands of northwestern India and elsewhere where it is listed as growing in the wild, the species is either found as a cultivated plant or as a remnant of old cultivation.

However, according to Popoola and Obembe (2013), *M. oleifera* is well-distributed in all the locations. In the Southeast of Anambra (Ifite, Awka) and Enugu (Ogwuoma), *Moringa spp* were found planted as hedges serving as boundary plants and in homesteads while in Delta State (Mangrove swamp), the plant was not only planted as hedges but also as fetish grove with a traditional priest in charge. While based to Saini et al. (2016), *moringaceae* is a single-genus family of shrubs and trees, which comprise 13 species, distributed in the Indian subcontinent (*M. oleifera* and *M. concanensis*), Kenya (*M. longituba* and *M. rivae*), northeastern and southwestern Africa (*M. stenopetala*), Arabia, and Madagascar (*M. drouhardii* and *M. hildebrandtii*).

Characteristics* of *M. oleifera

When it is in bloom, *M. oleifera*, a small deciduous tree with sparse leaves, may be mistaken for a leguminous plant from a distance. However, when it produces fruit, it is easily recognized. The tree attains a vertical extent ranging from 5 to 12 meters, while its diameter at breast height (dbh) is 60 cm (Liu et al., 2021; Orwa et al., 2009). The trunk is contorted, often bifurcating into two branches close to the base. The bark exhibits a sleek and charcoal hue, accompanied by subtle yellowish streaks. The twigs and shoots are densely coated with fine hairs. A crown is wide, unfolded, often resembling an umbrella, and usually composed of a solitary stem. It is frequently profoundly ingrained. The timber has a low density and is highly compressible.

Figure 2: *M. oleifera flower* (Hurtado-Torres, 2021)

The plant exhibits a phyllotaxis characterized by an alternate arrangement of its leaves, with the senescent leaves being shed promptly. Each leaf is rather sizable, with a length of approximately 90 cm (Hassanein & Al-Soqeer, 2018). The leaf structure is composed of compound leaves that are three-pinnate. The contralateral pinnae are positioned approximately 5 cm apart along the median axis. Furthermore, there is a secondary collection of contrasting pinnae, which bear leaflets organized in pairs. The terminal leaflet exhibits a significantly greater size compared to the remaining leaflets. The leaflets exhibit a dark green hue on their upper surface and a pale colouration on their underside. Occasionally, the colour appears as petiole yellow, characterized by a yellow or white hue devoid of any red streaks. They exhibit

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variation in size and shape, but generally have a rounded-elliptical appearance and measure between 12 and 18 mm in length, with few instances reaching 2.5 cm.

Besides, *M. oleifera* produces bisexual flowers that are present throughout the year and are highly cross-pollinated due to delayed stigma receptivity, and successful pollination requires a large number of insects (Bhattacharya & Mandal, 2004). These blooms are arranged in loose axillary panicles, which can grow up to 15 cm long. Every flower possesses a slender stem that has the potential to reach a length of 12 mm. Five sepals are pale green in colour. Each sepal measures 12 mm in length and is adorned with delicate hairs. The flower is characterized by 5 asymmetrical white petals that are somewhat longer than the sepals. Five stamens possess anthers and five stamens that lack anthers. The bloom possesses a slim style. Furthermore, the blossoms emit a highly aromatic scent. The fruit is remarkable for its substantial dimensions, reaching up to 90 cm in length and 12 mm in diameter. It exhibits a periodically narrowed form and gradually narrows towards a point. The fruit is light brown in colour and has a three- (or occasionally four-) angled shape, with two grooves on each side. The object splits at every aspect, exposing the lines of round, dark-hued oily seeds, each accompanied by three delicate, paper-like wings.

Nutritional Value* of *M. oleifera

Since *M. oleifera* can tolerate both moderate frost and severe drought, it is commonly grown all over the world. Every portion of the tree is suitable for commercial or nutritional purposes because of its high nutritional qualities. Malnutrition can be effectively treated using *M. oleifera*, a member of the Moringaceae family. Because of the numerous vital compounds found in its leaves, pods, and seeds, *M. oleifera* is a highly nutritious plant. *M. oleifera* is claimed to have seven times the amount of vitamin C as oranges, ten times the amount of vitamin A as carrots, seventeen times the amount of calcium as milk, nine times the amount of protein as yoghourt, fifteen times the amount of potassium as bananas, and twenty-five times the amount of iron as spinach (Rockwood et al, 2013). Every part of *M. oleifera* has important nutrients and antinutrients. The leaves of *M. oleifera* are rich in minerals like calcium, potassium, zinc, magnesium, iron and copper (Selahvarzi et al., 2021; Srivastava et al., 2023). Anti-cancerous agents such as glucosinolates, isothiocyanates, glycoside compounds, and glycerol-1-9-octadecanoate are found along with phytochemicals such tannins, sterols, terpenoids, flavonoids, saponins, anthraquinones, alkaloids, and reducing sugar (Vengal Rao et al., 2018).

It has been stated that *M. oleifera* has high-quality, readily digested protein, which is dependent on the purity of its amino acids. The desiccated leaves may be used in animal and human diets as an additional source of protein. Since it has been proposed that supplementing with amino acids is vital in satisfying a considerable portion of an animal's protein and energy requirements, this protein content is particularly important nutritionally Hence, *M. oleifera* 's nutritional value is immense because it contains all the essential amino acids, vitamins, and minerals—in even higher concentrations than other foods that are usually classified as such based on their nutritional qualities. The tree can grow up to 3–5 metres in a year, requires minimal agricultural care, and is drought-resistant (Peñalver et al., 2022). Cancer treatments including radiation, chemotherapy, and surgery are costly and can cause negative effects. Because *M. oleifera* is safe, dependable, and natural at recommended dosages, it can be employed as an anticancer drug. According to studies, *M. oleifera* has the potential to act as an anti-neo proliferative agent, which would stop the spread of cancer cells. Leaf extracts, both

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soluble and solvent-based, are successful anticancer agents (Bhalla et al., 2021). *M. oleifera* leaf extracts are antioxidants and anticancer agents which induce Reactive Oxygen Species (ROS). The exact behaviour of the two contrary attributes of the leaves is yet to be explored. The compounds of the leaves that are held responsible for anticancer activities are glucosinolates, niazimicin and benzyl isothiocyanate (Guevara et al., 1999; Nakamura et al., 2002). *M. oleifera* 's low-fat level, high protein, mineral, dietary fibre, and folate contents indicated that it has promise for usage as a functional ingredient in food for humans. It is a possible source of food enrichment because it is also a source of Ca, Fe, Cu, and K, all of which have a high bioaccessibility (Gopalakrishnan et al., 2016).

Commercialization of *M. oleifera*

In the nation of Bangladesh and additional emerging nations despite their enormous potential for generating money and ensuring food security *M. oleifera* trees frequently appear to be underutilised (Rahman et al., 2024). The Ministry of Finance and Economic Development in Ethiopia reports that there is strong government interest in expanding the commercialization of high-value commodities (Tafesse et al., 2020). Additionally, the growing commercialization of *M. oleifera* in different regions of the nation has been explored. Additionally, it is stated that the product managed and exchanged at the Addis Ababa and local marketplaces is *M. oleifera* (Teshome et al, 2013). Given its rapid progress and rising demand both domestically and internationally, *M. oleifera* processing is one of the most promising and significant sources of income for developing nations (Tafesse et al, 2020).

Because of its many uses in industry, in medical purposes, and had high nutritional value, *M. oleifera* has received a lot of attention. It is widely accepted that *M. oleifera* was very recently introduced to Botswana, despite the fact the precise date of its introduction is unknown (Kwaambwa et al, 2012). Even though it was just recently introduced, *M. oleifera* is already ubiquitous throughout the nation, especially in Gaborone areas, and many city dwellers may frequently be seen growing the plant in their backyards (Kwammbwa et al, 2012). *M. oleifera* is the newest superfood, especially for an arid country like Botswana. It can be increased, made more widely available, and even consumed locally. The respondents stated that Botswana has a huge market and potential for *M. oleifera*; the main issue at hand, though, is that not enough people are aware of it (Seifu & Teketay, 2020). People's current purchase of imported *M. oleifera* products (Moringa juice and mageu) from South Africa is one sign that the plant has commercial potential in Botswana. There will be a chance to commercialise *M. oleifera* in the future if there is a market and demand for it (Seifu & Teketay, 2020).

Conservation Status of *M. oleifera*

The International Union for Conservation of Nature (IUCN) Red List of Threatened Species last assessed *M. oleifera*, commonly referred to as the drumstick tree, in 2019, categorising its status as Least Concern. (Roland, 2020). *M. oleifera*'s conservation status does not appear to be any threats that would affect it. The seed pods are collected as a vegetable, which could potentially lead to reductions in genetic diversity, but studies have found strong genetic differentiation (Shahzad et al., 2013). 20 germplasm accessions can be traced from Kenya, Tanzania, India, and Brazil. They are held in Taiwan, Kenya, and Brazil according to Genesys Global Portal on Plant Genetic Resources 2019. Its distribution includes numerous protected areas, where passive conservation is presumed (Roland, 2020).

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Based on the integrated framework of Blackburn et al. (2011), the introduction status of *M. oleifera* has been classified as Category E. According to the description provided, species in Category E are fully invasive, meaning that individual members spread, thrive, and procreate at many locations within a varying range of habitats and occurrence extents. Unfortunately, *M. oleifera* 's dispersion status was only noted at one quarter-degree, making knowledge of its current distribution sporadic and mostly unclear. No formal risk evaluations have been conducted for the species, and the impact of *M. oleifera* is stated as not reviewed under the status report (Mashamaite et al., 2020).

Prospects of M. oleifera

Recommendations for the use of plants like *M. oleifera* in nutrition and wellness can have a direct impact on individual and community health. Therefore, focusing research on specific health benefits such as diabetes management is important. The use of *M. oleifera* has been proven to cure more than 300 diseases. According to Gopalakrishnan et al. (2016), diabetes leads to several complications such as retinopathy, nephropathy and atherosclerosis. Therefore, *M. oleifera* can help prevent these diseases through Advanced Glycated End Products (AGEs). AGEs are produced as a result of the reaction between blood glucose and proteins that occurs when hyperglycaemia is present. These AGEs bind to receptors for advanced glycated end products (RAGE) which get expressed on the surface of immune cells. Moreover, *M. oleifera* can be used to fight cancer because it is natural, stable, and safe at established amounts. *M. oleifera* contains anti-neoproliferative properties, which means it can effectively hinder the spread of cancer cells. Thus, extracts of leaves, both soluble and solvent-based, have been demonstrated to be effective treatment agents for cancer (Gopalakrishnan et al., 2016). However, this recommendation also has limitations such as the fact that people with diabetes shouldn't just eat *M. oleifera*, and they shouldn't stop taking insulin or other medicines their doctor has recommended without first talking to their doctor. They should also make sure they get high-quality products and talk to doctors to make sure it's safe and right for diabetic patients.

Some nutrients are stored in every component of the plant. Minerals such as calcium, potassium, zinc, magnesium, iron, and copper can be found in the leaves of the *M. oleifera* plant (Islam et al., 2021). Moreover, leaves contain a low calorific value, making them suitable for inclusion in the diet of individuals who are obese and leaves also contain all essential amino acids and are rich in protein and vitamins (Thapa et al., 2019). Hence, for future recommendations, *M. oleifera* can be a helpful supplement (Mahfuz & Piao, 2019). The dry leaves have been reported to contain the vitamin C content of *M. oleifera*, which is seven times that of oranges (Gopalakrishnan et al., 2016). Therefore, drying and powdering *M. oleifera* leaves can be easily added to water, juice, or soups. Furthermore, powdering *M. oleifera* leaves can be added to fortified foods and snacks (Oyeyinka & Oyeyinka, 2018). To sum up, an increased focus on nutritional value emphasising its abundant vitamins and minerals can develop *M. oleifera*'s nutritional profile effectively. Thus, conducting more studies on the long-term effects of *M. oleifera* consumption on human health is compulsory.

M. oleifera promotes sustainable cultivation and distribution. The plant is grown in numerous nations across Africa, Central and South America, Sri Lanka, India, Pakistan, Mexico, Malaysia, Indonesia, and the Philippines (Roland, 2020). Its cultivation is primarily to utilise it as food, medicine, and animal feed. Hence, the government can promote the cultivation of *M. oleifera* within local communities for both personal consumption and generating income (Devkota & Bhusal, 2020). This enhances the capabilities of communities and diminishes their

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dependence on centralised production. Not only that, but the government can also enable seamless linkages between *M. oleifera* producers and customers using cooperatives, farmers' markets, and online channels. This eliminates intermediaries and guarantees equitable rates for farmers. Moreover, to increase demand and encourage responsible consumption, it is important to educate consumers about the nutritional benefits and sustainable practices that are associated *with M. oleifera*. To make the most of the plant's potential, it is important to encourage research on improved *M. oleifera* varieties, processing processes, and additional nutritional interventions.

The future recommendations for *M. oleifera* are important because it has a lot of health benefits for people and communities, especially when it comes to beating cancer and diabetes (Al-Asmari et al., 2015; Oguntibeju et al., 2020). Moreover, because they are low in calories and high in important nutrients, the plant's leaves can be used to add to and improve many foods (Srivastava et al., 2023). In addition, promoting sustainable farming and delivery around the world can help communities become more self-sufficient ((Hume et al., 2021). Therefore, there must be ongoing research on the long-term impact of *M. oleifera* on health. Effectively using the potential of *M. oleifera* necessitates adopting a well-rounded strategy that integrates the advantages it offers for health, while also ensuring sustainable practices and empowering the community.

Conclusion

M. oleifera emerges as a botanical treasure with global significance. This adaptable plant has its origins in Northwestern India and its historical significance is intricately linked to its current importance, which is attributed to its valuable contributions in the fields of industry, agriculture, and nutrition. *M. oleifera* is a possible ally in the fight against diseases such as diabetes and cancer due to its leaves' exceptional nutritional content and potential health advantages. The growing commercialization of *M. oleifera*, especially in countries like Bangladesh and Botswana, highlights its economic viability. Continued research is necessary to understand the long-term health effects of consuming *M. oleifera*, even though its conservation status is now reassuring. The narrative is strengthened by the inclusion of sustainable cultivation practices and the promotion of community empowerment. This underscores the need for a comprehensive strategy to fully exploit the capabilities of this exceptional plant, which benefits both individuals and the environment.

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