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Moringa oleifera - A comprehensive review on its nutrition and pharmacological activities

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Abstract
Moringa oleifera, a tropical tree also known as the horseradish tree, is highly valued for nutritional and medicinal properties in several countries. In the past few decades, several scientific studies have validated many traditional claims about the usage of different parts of *M. oleifera* for the treatment of a variety of diseases such as rheumatism, stomach disorders, headache, asthma, intestinal complaints and fevers, and cardiac problems. Among the various pharmacological properties of *M. oleifera* are its analgesic, anti-inflammatory, diuretic, antihypertensive, antimicrobial, and anticancer potential characteristics. There are other phytochemicals in this plant as well, a few of which are particularly significant because of their potential medical uses. *M. oleifera* has been reported to have beneficial properties in almost all parts of the plant, and hence it is used for a variety of medicinal purposes. An introduction for essential minerals, as well as carotenoids, amines with different aromatic compounds are available in the whole parts of this medicinal plant. Some important naturally occurring compounds are caffeoylquinic acid, kaempferol, quercetin, and zeatin, which are present in higher concentrations in *moringa*.

Keywords: *M. oleifera*, commercial application, traditional uses, therapeutic activity, kaempferol

Introduction
The Moringaceae family originated in the northern Himalayan region, extending across Pakistan, India, and Afghanistan. *M. oleifera* is the most widely grown and well-known species in its family. Even though its wood is not very good, people have used the plant for many years for food, medicine, and various practical uses. The edible parts of the tree have been eaten for generations and play a major role in supporting nutrition and health in many communities [1]. Among the lesser-known but highly valuable plants included in the educational concerns for hunger organization seed collection list, *M. oleifera* is considered one of the most popular species grown in warm climates worldwide. It is known by numerous names across different cultures. Commonly called the "*miracle tree*" in India, it is also referred to as "malunggay" in the Philippines, where fried leaves are fed to infants, and the "Benzolive plant" in Haiti, as well as by various names in Senegal. The genus comprises approximately 13 distinct species of drumstick trees [2]. The various parts of this important tree offer many different health benefits. In South Asian traditional medicine systems, nearly every component, including the roots, bark, leaves, resin, and pods, is used to treat numerous conditions such as inflammatory disorders, infectious diseases, and cardiovascular ailments.

Fig 1*:* *Moringa Oleifera* – pods & Flowers (3)

Plant Profile
Synonyms: Hyperanthera moringa, *Moringa pterygosperma* Gaertn**,** and Guilandina moringa Lam (4).

Table 1: Science categorization of *M. oleifera* (5)

Kingdom	**Plantae**
Division	Mangoliophyta
Class	Violes
Order	Moringa
Species	*M. Oleifera*
Family	Moringaceae

Different parts of *M. oleifera*
Stem
Despite its inherent length, the stem occasionally lacks proper form. The tree is between 1.8 and 3 meters tall, with a short, straight stem [15].

Medicinal uses of stem:
It is also applied to prevent delirium in patients, prevent splenic enlargement and the development of neck tuberculous glands, eliminate cancer, and any disease. Stem is applied to the ears to treat earaches and acts as an anti-tubercular agent.

Leaves
The feathery, tripinnate compound leaves possess grass, curving flyers which measure between one and four centimeters in length. As seen in Figure 3, the alternating two or three leaves typically appear towards the sections' termini. When young, they have a long petiole with pairs of leaflets. They are 20 -70 cm long and grayish in color [16].

Flowers
The flowers are Large, delicately scented flowers are carried on inflorescences that are two centimeters in dimension, and fifteen to twenty-five centimeters in length, and mostly white to cream in color, though some variations may have a

hint of pink The blooms, which are 2.5 cm wide and have a pleasant scent, are abundantly distributed in supplementary, falling clusters with lengths of ten to twenty-five centimeters. 5 reflexes are straight and lanceolate. The petals are thin and slender.

Fruits

Fruits, sometimes known as pods, are trilobed shells. Young pods have a few radishes shading and are green in certain varieties. When dry, the brown, oval seeds split into three sections lengthwise. Which size is 35–130 cm long, 12.8 cm wide, with around 20 seeds inserted within fiber.

Seeds

The grains are round, brown in color, impermeable with 3 paper-like lobes. Nut patterns typically brownish from light to deep, even though portions are not particularly effective, they may occasionally white. From the beginning, the structure's three white feathers run continuously, ending at intervals of 130 seconds [17]. The preventive effect of the seed extract is achieved via lowering liver lipid peroxides.

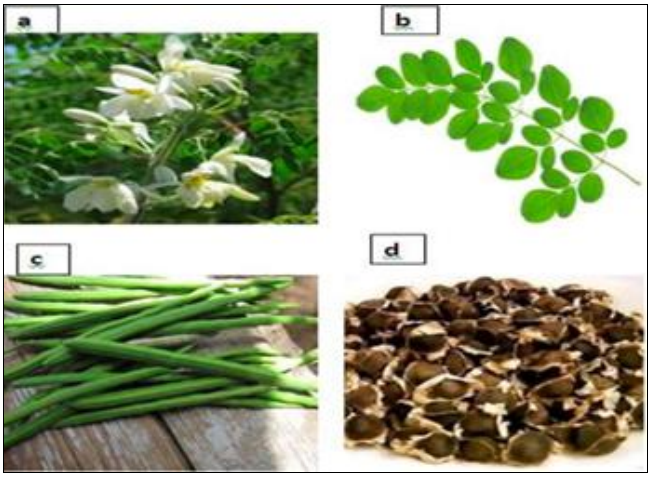

Fig 2: Different parts of *M. oleifera* (a) flowers (b) Leaves (c) Fruits (d) Seeds (18-19)

History, range, and state of growth of *M. oleifera*

The common multipurpose tree, *M. oleifera*, is said to have various industrial uses, as well as nutritional, medicinal, and preventive qualities. The ancient world was aware of it, but due to its incredibly wide variety of possible applications, it has only lately been rediscovered. This perennial tree grows quickly and can grow up to between seven and twelve meters tall at the top [20]. It was discovered growing organically as much as a thousand meters above the ocean's level. It is an uncultivated plant; it is more commonly seen growing in river basins or on grazing land. A single-gen Moringaceae, A group of plants that includes *M. oleifera*, is a member. At the start of the 20th century, it was brought to Eastern Africa from India, and it is currently developed via the region's Mediterranean and nearly all of it region's tropics [21].

Climate Requirements

M. oleifera grows in a wide variety of climates. It is an evergreen tree that grows quickly in moderate temperatures with high humidity, though it can occasionally appear to be a deciduous tree in stressful situations like low temperatures below five C or high temperatures above fifty degrees Celsius during a drought. This tree is suited for semi-arid tropical and semi-tropical climates because it requires 200–2000 mm of rainfall annually within twenty-five and forty degrees Celsius for development. Moringa was often grown or farmed in many nations in Africa, Southeast Asia, South America, and America. *M. oleifera*, one of the fourteen species in this genus that are indigenous to Egypt, Nigeria, and India, is the most widely distributed and farmed species [22].

Table 2: Ecological Requirements of *M. oleifera* (23)

Sr. No.	Parameters	Requirements/ Range
1	Weather conditions	The hot zone
2	Thermal level	Around 19 to 29 °C
3	Soil type	Grainy to the touch and drains well
4	Soil pH	Neutral

Propagation

Direct seeding, seedling transfer, and mature stem cuttings are the main methods used for propagating moringa. When the growth rate is high, direct sowing is the better option. The greatest depth at which seeds can be sown is 2 cm, as deeper sowing may result in a lower germination rate. A kilogram of Moringa seeds (with their shell) contains about 4000 seeds, and the germination rate is between 78 and 94%. Five to twelve days after sowing, moringa seeds begin to sprout [24]. Seeds are sown 2 cm deep in polythene bags or sacks filled with topsoil, and they are watered once every two to three days. Once they have been sown, they must be kept out of direct sunlight and shielded from heavy rain. Before being transplanted, the immature Moringa plants must be fostered for four weeks until they are around thirty centimeters high. When the plant is being transplanted, the plastic bag should be removed so the roots are not damaged [25].

Planting

It grows well in warm, humid weather and grows best in clay or clay-type soils that drain water properly. For a seed to germinate well, it needs to be somewhat fresh. Germination depends on warm temperatures. Given that it is a delicious grain regarded as a delicious nibble by forest snakes and rodents, planted seeds should be protected from them. Spring and summer are also good times to plant stem cuttings, which are 10–60 cm long [26].

Phytochemical constituents of *m. Oleifera*

As per the current investigations shows the presence of numerous derivatives in this plant. Based on the scientific data obtained, more than ninety chemicals have been established in this plant, most of them having therapeutic properties due to they contain a plethora of phytochemicals and secondary metabolites that have been extensively used in different sectors [6]. Compared to other plants, *M. oleifera* contains higher quantities of flavonoids and phenolic acids. The flavonoids kaempferol, catechin, myricetin, and quercetin [7] are thought to provide exceptional therapeutic efficacy. The plant's therapeutic effectiveness is attributed to significant components in its leafy parts [8]. Various techniques were used to identify about 35 chemicals in the plant's leaves [9]. Around 35 different compounds have been identified in the leaves of *M. oleifera*, including hexadecanoic acid, 3-hydroxy-β-ionone, quercetin, and bis (isothiocyanatomethyl) benzene. The plant also contains

glucomoringin [10]. Studies show that the pods and leaves hold plant sterols, essential oils, and the compounds niaziminin A and B, along with saponins [11]. The seeds contain rich various lipids [12]. In addition to known constituents such as benzyl isothiocyanate, β-sitosterol, niazimicin, niazirin, glycerol-1-(9-octadecanoate), and 4-O-(6′-O-oleoyl-β-D-glucopyranosyl), researchers have also identified a new compound in the ethanolic seed extract: O-ethyl-4-(α-L-rhamnosyloxy) benzyl carbamate [13]. Figure no. 2 displays these main plant chemicals that were taken out of this plant & their structures. Vitamins C, A, and a variety of amino acids are found in moringa leaves.

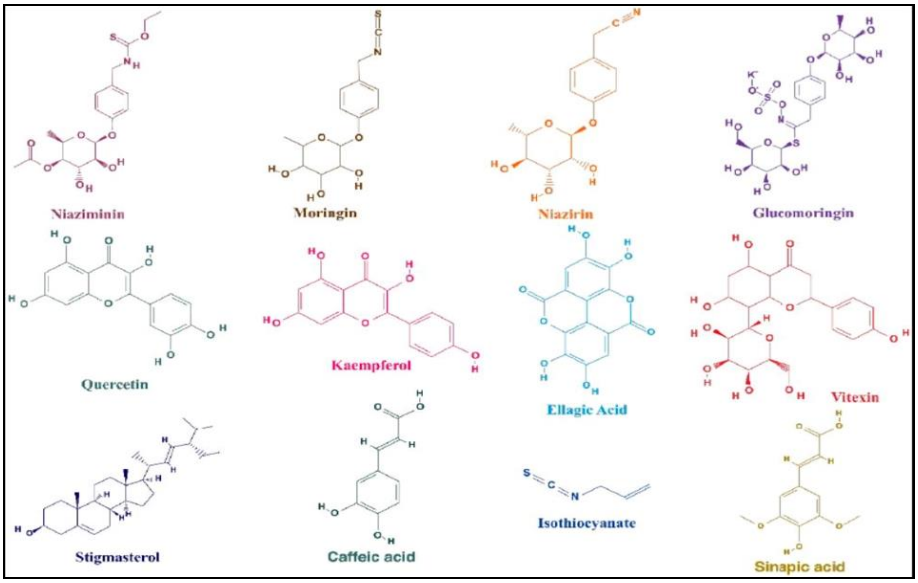

Fig 2: Phytochemical constituents of *M. oleifera* (14)

Traditional uses of *m. Oleifera*

Ben oil

Because of its elevated oil content from Moringa seeds known as ben oil is 38–40%. In comparison to other plant oils, this oil has no smell, transparent, & resistant to Rancidness. After ben oil is extracted, the seed cake that is left over can be utilized. The fluid content from the plant material, known as "oil of Ben," is applied to skin ailments and used to treat earaches. It is claimed that applying the oil to the skin keeps mosquitoes from biting.

Water Treatment

Turbid, unclean water can be clarified by grinding seeds into a powder. The method of cleaning involves the establishment of electrical charges between the ground seeds and the muddy particles floating in the water. Gravity causes the dirt particles to settle at the bottom. Cattle can benefit greatly from moringa as feed. It seems that the dried leaves work considerably better.

Biogas

Additionally, the leaves can create methane gas. Research has demonstrated that 4,400 cubic meters of biogas may be produced annually per hectare.

Applications in Industry

The pressed cake can be used as a pesticide. The piece and the clothing sector employ the *M. oleifera* for its wood, and the tanning industry for its bark [27].

Traditional Uses

The seed oil can be used to lubricate watches and other delicate equipment, as well as in the arts and in the manufacturing of hair conditioners and perfumes. The drumstick tree is utilized for its wood in the paper & textile sectors as well as for its bark in the tanning industry [28]. Fried seeds have antiparasitic and antibacterial properties and are used to treat hyperglycemia. Liquid from roots has antiepileptic and heart tonic properties. Additionally, this is used as a fundamental infection. The leftover cake produced after the oil is extracted can be used as a fertilizer. Swelling of the liver also in the urinary tract infection. Mental weakness, and asthma. The decoction is gargled to relieve sore throats and hoarseness. Fruit and root are antiparalytic. According to Indian pharmacies Ayurveda dried root bark (together with dried seeds) can be used to treat lipid problems, goiter, and glycosuria. It can also be used to treat internal abscesses and piles [29].

Nutrition

Key nutrients and antinutrients are stored in every section of *M. oleifera*. The leaves of *M. oleifera* are abundant in minerals, including iron, copper, zinc, magnesium, potassium, and calcium [30]. Without refrigeration, leaves may be consumed raw or prepared, or it might be kept in dry granules to be used for several weeks without losing their nutritious content. Numerous data on Moringa's nutritional benefits can now be found in both popular and scholarly journals. Users becoming skilled in Moringa plant will recognize the frequently mentioned statement from the plant history organization, a long time back it "ounce-for-ounce, Moringa leaves contain more Vitamin A than carrots, more calcium than milk, more iron than spinach, more Vitamin C than oranges, and more potassium than bananas. In oral experiences that in Senegal and throughout West Africa, Lowell Fuglie kept a record of occurrences and activities that will also be familiar to these readers [31].

Pharmacological activity of *m. Oleifera*

Antioxidant

Antioxidants are crucial in preventing and scavenging free radicals, which shield people against infections and

degenerative illnesses [32]. Because of their safety, natural antioxidants derived from plants have become the focus on several researchers [33]. In Indian traditional medicine, *M. oleifera* is used to treat a variety of illnesses. Several researchers have extensively studied the pharmacological potential of *M. oleifera* leaves, particularly their antioxidant actions. It has been well documented in several studies that the antioxidant qualities in the leaves of Moringa have been examined through conventional laboratory systems to understand the mechanisms of their pharmacological effects. *M. oleifera* consecutive aqueous extract shows potent scavenging activity on superoxide and nitric oxide radicals and inhibits lipid peroxidation. The extracts of the leaves can prevent oxidative stress, showing efficacy comparable to reference antioxidants. Earlier studies have provided substantial evidence supporting the role of *M. oleifera* phytochemicals in reducing oxidative damage. According to the information gathered for this study, extracts of *M. oleifera* leaves, both tender and mature, show strong antioxidant properties [34].

Antiinflammatory

Several researchers have extensively studied distilled ethanol to extract *M. oleifera* seeds, which were then concentrated at 40°C under reduced pressure [35]. Hexane, ethyl acetate, butanol, and water were used to separate the extract. The hexane fraction reduced inflammation by 77%, while aqueous fractions reduced discomfort by only 34%. Several researchers show that both the ethanol and hexane extracts from Moringa seeds have strong anti-inflammatory effects [36]. Which agrees with several other studies. In contrast, the ethyl acetate extract was found to be toxic and increased discomfort by 267% [37].

Antimicrobial activities

The roots of the drumstick tree contain natural substances that help stop the growth of harmful bacteria. One of the key compounds, known as pterygospermin, is particularly strong in its antibacterial action. A similar type of compound is also responsible for the plant's ability to fight both bacteria and fungi. The presence of 4-methyl-rhamnosyloxy benzene isothiocyanate in the root tincture also contributes to its antibacterial action. It has been well documented that an alcoholic tincture of roots and its chloroform fraction containing the aglycone of deoxyniazimicine shows antimicrobial properties. The outer sap of the trunk exhibited antibacterial effects against Staphylococcus aureus, whereas the outer layer extract also showed antimicrobial activity [38]. Earlier reports highlighted the therapeutic importance of *M. oleifera* root and bark extracts in managing microbial infections [39].

Antiasthmatic activities

Early data show twenty people with mild to moderate asthma participated in a three-week trial, receiving three grams of finely ground dried seed kernels [40]. Spirometry readings before and after treatment demonstrated improved respiratory function. Hemoglobin levels increased, and erythrocyte sedimentation rate decreased. Both the severity of asthmatic episodes and symptom scores showed notable improvement. Earlier studies have provided substantial evidence supporting the role of *M. oleifera* seed kernels in improving respiratory health and reducing asthma symptoms [41].

Analgesic activities

For many years, people have turned to *M. oleifera* in traditional healing practices to ease problems such as gout, eye infections, and arthritis. Studies also show that its seeds can fight microbes and can even help clean water [42]. Extracts made from the leaves using alcohol have been found to reduce pain, but similar effects from the seeds have not yet been reported. During analytical evaluation, ethanol tincture, and its fractions—including gasoline, ethyl ether, and n-butanol—were assessed for tannins, proteins, and sugars. The typical dose of aspirin used for comparison was 25 mg/kg [43]. Several researchers have extensively studied the pharmacological potential of *M. oleifera* extracts in pain-modulating mechanisms.

Anthelmintic activities

Worm infections continue to be a serious problem in many places, harming both people and farm animals. In humans, these infections can lead to serious issues like weakness, malnutrition, blindness, and deformities. Farmers also struggle with these diseases in their animals, especially small livestock, because they reduce growth and productivity. Medicines called anthelmintic are used to remove these worms, but very few new drugs have been discovered in the last thirty years. Some researchers have found that *M. oleifera* contains certain natural compounds that might help fight parasites [44].

Antidiarrheal activities

Folk medicine suggests *M. oleifera* as a treatment for several ailments, including rheumatism, lumbago, asthma, gout, and liver/spleen enlargement [45]. No pharmacological investigation had assessed the antidiarrheal potential of its rhizome until recent studies. Hydroalcoholic [50] extracts of *M. oleifera* root were examined for antidiarrheal activity in rat models of castor-oil-induced diarrhea [46]. The evaluations included reduction of frequency, severity of diarrhea, intestinal fluid accumulation, and electrolyte content. The several researchers show that *M. oleifera* root extract has strong healing effects and that the experimental model is useful. Previous studies also support its role in treating digestive problems. However, more research is needed to identify and understand the chemicals it contains [47].

Antinociceptive activities

Several studies have reported similar findings, indicating that acetic acid–induced writhing, formalin paw-licking, and tail immersion tests were used to assess the antinociceptive properties of fresh leaf juice and ethanolic extracts. Mice exhibited notable pain-relieving effects at 100 mg/kg. The opioid antagonist naloxone reversed the effect, indicating CNS and PNS opioid receptor involvement [48]. In earlier research, the mechanism of action was evaluated using HMG-CoA reductase activity, showing increased fecal cholesterol excretion and hypolipidemic effects [49].

Antinociceptive and antipyretic activities

Rheumatoid arthritis is a chronic multisystem disease with unknown cause. *M. oleifera* and Ayurveda-based formulations such as Mobilax are used traditionally to manage arthritis, spondylitis, and chronic pain [50]. Animal models were used to assess antipyretic and analgesic effects of these formulations. Brewer's yeast–induced pyrexia tests

showed antipyretic properties comparable to paracetamol (150 mg/kg) [51]. Earlier studies have pointed out that remedies made from Moringa have been useful in easing inflammation and joint-related problems.

Wound healing activity

Many studies have looked at how *M. oleifera* leaves help wounds heal and support recovery from different conditions. Experiments in rats, where wounds were closed with stitches or created using dead tissue, showed good results at a dose of 300 mg/kg. The treated wounds had more collagen and better tissue rebuilding. Researchers also report that Moringa helps repair wounds by boosting collagen formation and supporting healthy tissue growth [52].

Discussion

M. oleifera is exceedingly valuable plant because of its high nutrients and medicinal properties. It has phytochemicals including flavonoids, phenolic acids, vitamins and isothiocyanates that render it good antioxidant, anti-inflammatory, antimicrobial and protective effects. These properties justify its use in the treatment of inflammation, infection, indigestion and metabolic diseases. Leaves and seeds are packed with powerful antioxidants and anti-inflammatories, whereas roots and bark help fend off those nasty microbes we discussed before, as well as diarrhea. Molecules such as niazimicin and benzyl isothiocyanate also reveal themselves suitable candidates toward the discovery of new drugs. Most research to date has used crude extracts, and more focused studies, including the isolation of active compounds, testing safety and performing clinical trials are still required. Overall, *M. oleifera* is a versatile plant having traditional and modern applications.

Future Prospective

M. oleifera been gaining scientific attention as a versatile tree for its myriad of nutritional, medicinal and industrial uses. The isolation and characterization of the bioactive compounds of LC need to take precedence for standardization with further pharmacological studies as a part of the preparation for evidence-based phytopharmaceuticals. Additionally, modern analytical tools (metabolomics, proteomics and genomics) will also enable more in-depth knowledge of its complicated phytochemical composition as well as the molecular mechanisms underlying its biological action. The potential of *M. oleifera* is high in the nutraceutical and functional food approaches, particularly to respond to diseases of malnutrition, metabolic disorders and disease states related to oxidative stress. Nevertheless, the results need to be confirmed by larger clinical studies. Is needed to prove its efficacy, determination of safe dosage range and long-term safety. In addition, sustainable cultivation and post-harvest processing technologies must be developed to produce a consistent quality with optimal yield of bioactive constituents. Moreover, the plant's role in bioremediation, wastewater treatment and biofuel production offers novel prospects in environmental and industrial settings. Overall, *M. oleifera* appears to be a highly promising plant as its multipurpose status suggest; however, further progress will depend on robust clinical validation, well-characterized formulations, and industrial scaling up with respect of documented knowledge passed by traditional use.

Conclusion

M. oleifera is an economically and nutritionally important tropical tree species cultivated in the developing countries having suitable agro climatic region. Its different parts, such as leaves, seeds, pods, have many functions and the yield can be maximized for human usage. Although many studies on various parts of *M. oleifera* have been conducted, much work is required for the identification and characterization of more novel bioactive compounds with distinctive promoting or inhibitory functions. Moreover, seed control extracts with flocculating proteins showed coagulation efficiency of cloudy water.

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