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Moringa: An underutilized multipurpose powerful vegetable for nutritional security

Moringa is a remarkable plant that has earned its reputation as a 'miracle tree' due to its exceptional nutritional, medicinal, and environmental benefits. From its nutrient-rich leaves and pods to its drought-resistant nature, the moringa tree's significance extends far beyond its humble appearance. Furthermore, moringa is gaining popularity as a value-added ingredient in the production of functional foods. It has been widely used as a beneficial dietary supplement due to its strong defense against various illnesses and its ability to counter environmental toxins. Therefore, it is necessary to explore its potential applications and evaluate its medicinal properties, which could pave the way for developing new drugs and functional foods.

Keywords: Bioactive compounds, Functional foods, *Moringa oleifera*, Nutritional value, Sustainable agriculture

MORINGA (*Moringa oleifera* Lam.) belongs to the family Moringaceae. Revered for centuries in various cultures for its medicinal and dietary benefits, moringa's diverse array of nutrients and potential health-promoting properties makes it a true wonder of nature. Native to the Indian subcontinent, it is widely grown in South Asia, Africa, and South America. India is the largest producer of moringa, with an annual production of about 2.6 million tonnes of fruits from 43,600 ha, achieving an average productivity of around 63 t/ha. Among the major states, Tamil Nadu ranks first in area and production, followed by Andhra Pradesh and Karnataka.

This versatile tree has gained global attention for its various uses and contributions to human health, sustainable agriculture, and biodiversity, and is hailed as a superfood. Traditionally, it has been used in Ayurvedic medicine, yet its potential remains underutilized as a staple food. It is a versatile plant, with nearly all its parts, leaves, fruits, flowers, and young pods, being consumed worldwide as vegetables. The tender green pods are commonly prepared and used as a vegetable ingredient. Nutritionally, it is rich in protein, vitamins A and C, calcium, and antioxidants such as quercetin. These components can undergo minimal processing and be incorporated into diverse culinary dishes. Despite extensive research on identifying and quantifying the beneficial compounds in moringa leaves, there is a lack of studies examining their bio-accessibility and bioavailability.

Botany

The moringa tree is known for its rapid growth, typically reaching heights of up to 12 m. It features a delicate trunk adorned with greyish-white bark. Its branches droop and bear compound leaves arranged spirally, each comprised of numerous oblong or elliptical leaflets, typically measuring 1.2–2.0 cm in length and 0.6–1.0 cm in width. The tree bears yellowish creamy-white flowers, which are bisexual, and the pods are long and pendulous. Moringa seeds are trigonous in shape.

Production technology

This plant thrives in drier climates due to its drought-resistant nature. Although moringa can grow in a variety of soil conditions, it performs best in well-drained loamy and sandy soils with a pH range of 5 to 9. A temperature range of 25°C to 35°C is ideal for its growth. Cultivars occur in two forms – perennial and annual. It can be propagated by stem cuttings or seeds. Typically, it is planted from July to October. About 500 g of seed are required per hectare. After sowing, seedlings should be transplanted 30 to 40 days after sowing (DAS). Trees should be planted 3 meters apart for intensive cropping.

Aftercare practices such as irrigation and weeding should be properly followed. Apply 10–20 kg FYM per tree. NPK at 150:150:100 kg/ha may be used as a basal dose. Once established, the tree requires minimal irrigation. Pruning should be carried out about 18 months after planting. Pods should be harvested when they are still tender and snap easily. Leaves can be harvested when the plants reach a height of 150–200 cm, and about 50–55 tonnes of pods can be produced per hectare.

Important varieties of moringa

PKM-1: It is an annual variety suitable for both pod and leaf production, with a yield potential of about 53 t/ha.

PKM-2: This is a high-yielding variety harvested 7–8 months after planting. It produces extra-long pods

measuring about 126 cm and has a yield potential of around 98 t/ha.

Thar Harsha: An annual variety with a yield potential of 53–54.7 t/ha, or approximately 314 pods per year. It is drought-tolerant and possesses a higher antioxidant content.

Thar Tejas: An annual moringa variety developed from local germplasm, suited to arid and semi-arid regions. It is drought-tolerant, rich in antioxidants, and yields about 53–54 t/ha with long, tender pods suitable for both vegetable and leaf production.

Bhagya: An annual moringa variety developed as an improvement over PKM-1. It flowers within 6–7 months, yields 40–45 t/ha of long, tender pods, and is drought-tolerant, making it suitable for semi-arid regions.

MOMAX3: A perennial cultivar developed by the Advanced Biofuel Center for seed and oil yield. It is an early-bearing type, beginning production within 4–6 months after planting, and has a seed yield potential of 8–10 t/ha.

MOL'E: A variety specifically developed for leaf production, capable of yielding about 30 tonnes of dry moringa leaves per hectare.

Nutritional values

Its leaves, pods, and seeds are rich sources of essential nutrients that contribute to overall health. The leaves, in particular, are brimming with vitamins and minerals, including vitamins A, C, and E, as well as iron, calcium, potassium, and protein. Moringa is rich in essential amino acids and contains a significant amount of provitamin A. Studies have reported that moringa leaves contain 16–19 amino acids, including 10 essential amino acids such as lysine, phenylalanine, methionine, tryptophan, leucine, isoleucine, histidine, threonine, tyrosine, and valine. In terms of fatty acid composition, moringa leaves are particularly abundant in unsaturated fatty acids, with α-linoleic acid being the most prominent. Moringa also contains minerals such as potassium, magnesium, zinc, iron, and copper. Additionally, it provides fat-soluble vitamins, including vitamin A (as beta-carotene), vitamin D, and vitamin E, as well as water-soluble vitamins like vitamin C and B-complex vitamins such as folic acid, pyridoxine, and nicotinic acid. The nutritional composition of moringa varies depending on climatic conditions and varietal differences.

The composition of nutrients varies among different parts of the moringa plant–leaves, pods, and seeds. The leaves provide 92 calories per serving and are rich in carbohydrates (12.5 g), protein (6.7 g), minerals (2.3 g), and fats (1.7 g). They are a good source of calcium (440 mg), potassium (259 mg), sulfur (137 mg), phosphorus (70 mg), magnesium (42 mg), and iron (0.85 mg), and contain high levels of vitamins, including vitamin A (11,300 I.U.), vitamin C (220 mg), and vitamin E (448 mg). The pods contain carbohydrates (3.7 g), protein (2.5 g), fat (0.1 g), and fiber (4.8 g), along with minerals such as phosphorus (110 mg) and iron (5.3 mg). They also provide 120 mg of vitamin C and 184 I.U. of vitamin A. The seeds contain considerable amounts of protein (35.97 g), fat (38.67 g), magnesium (635 mg), phosphorus (75 mg), calcium (45 mg), sulfur (0.05 mg), and vitamin E (751.67 mg).

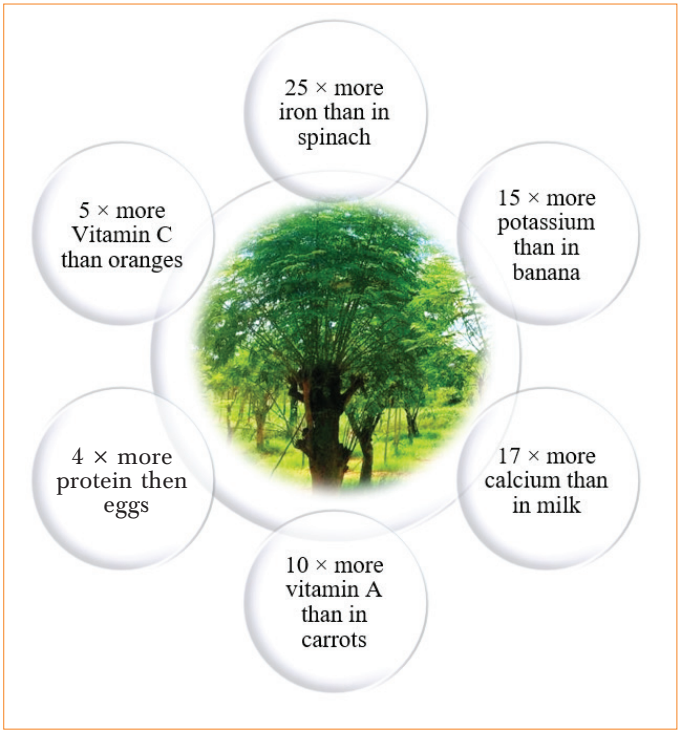
Flowering

Pods

Seeds

Leaf powder

Seed powder



Medicinal value of moringa

One of the most remarkable aspects of moringa is its potential to strengthen the immune system. Its high vitamin C content enhances the body's ability to fight infections. Vitamin A supports healthy skin and mucous membranes, which serve as the body's first line of defense against pathogens. The presence of zinc in moringa also contributes to immune function and wound healing. Additionally, the high fiber content in moringa pods helps stabilize blood sugar levels and promotes digestive health. Research suggests that compounds such as isothiocyanates may help regulate blood sugar levels. The rich antioxidant content of moringa helps combat free radicals, thereby potentially reducing the risk of chronic diseases. Its anti-inflammatory properties further contribute to overall health by mitigating the inflammation cascade that can lead to various health issues. The leaves and pods are believed to possess anti-inflammatory, antimicrobial, and antioxidant properties. The seeds, when crushed, yield nutrient-rich oil that has been used for its antiseptic and anti-aging properties.

Traditionally, in India, moringa leaves have been used as a medicinal remedy for ailments such as conjunctivitis and intestinal worm infestations. Additionally, fresh moringa leaves are known to enhance milk production in pregnant and lactating mothers and are used in the management of anemia. In individuals with diabetes, moringa leaf juice has been traditionally used to help regulate both blood glucose and blood pressure levels. Moreover, due to their abundance of polyunsaturated fatty acids like omega-3 and omega-6, moringa leaves are believed to support cardiovascular health and overall vitality. Moringa also exhibits notable anti-cancer properties, with its usage considered safe, natural, and dependable within certain limits. Due to the release of gamma-aminobutyric acid (GABA), moringa leaves have long been used in traditional medicine to support the management of central nervous system disorders such as epilepsy and Alzheimer's disease. The neuroprotective effects are largely attributed to the flavonoids present in the leaf extract.

Bioactive compounds in moringa

The phytochemical composition of moringa plants varies depending on factors such as genotype, maturity stage, agro-climatic conditions, storage conditions, and time. Moringa leaves are rich in phytochemicals, including phenolic acids, isothiocyanates, flavonoids, saponins, alkaloids, tannins, and anthraquinones, many of which are known for their anti-cancer properties. They also contain antioxidants such as quercetin and chlorogenic acid, which help counteract oxidative stress. Among the significant phytochemicals present in the leaves are cryptochlorogenic acid, quercetin, and astragalin, all of which contribute to antioxidant, anti-hypertensive, and anti-inflammatory activities.

Flavonoids, particularly quercetin, apigenin, kaempferol, luteolin, and myricetin glycosides, are major phenolic compounds found in moringa leaves. Carotenoids, also abundant in the leaves, serve as potent antioxidants, although their levels may be influenced by environmental factors, post-harvest handling, and cooking methods. Additionally, moringa leaves contain folates, tannins, saponins, and fatty acids, with folate being essential for cellular metabolism. The leaves also exhibit higher levels of polyunsaturated fatty acids and lower levels of monounsaturated fatty acids compared to the pods. Tannins, which are soluble polyphenolic compounds, can precipitate proteins and other biomolecules. Although moringa contains trace amounts of antinutrients such as phytates, tannins, and oxalates, which may interfere with nutrient absorption when consumed in excessive quantities, moringa oleifera remains non-toxic and highly beneficial when consumed in moderation.

Table 1. Medicinal properties of moringa

Plant part	Uses
Whole plant	Anti-tonsillitis, anti-cancerous
Flower and bark	Anti-inflammatory, stimulant, diuretic, antibiotic, aphrodisiac, cholagogue
Flower buds, leaves and gum	Hypoglycemic, anti-diabetic, diuretic, anti-inflammatory, antispasmodic, antibacterial, rheumatism, abortifacient, anti-ulcerogenic
Seed	Anti-pyretic, anti-irritant, anti-inflammatory, diuretic, antiascitic, antipasmodic, antirheumatic
Root	Antibiotic, antipalsy, antirheumatic, antihysteric, antiepileptic, antihepatotoxic

Culinary values of moringa

The tender leaves and pods are used in various regional recipes, adding a distinctive flavour and significant nutritional value to traditional foods. Moringa leaves can be incorporated into salads, soups, and smoothies, providing a nutrient boost without significantly altering taste. Moringa pods are commonly used in curries, stews, and other dishes, contributing both flavour and nutrition. They are a staple ingredient in South Asian cuisine, where they are frequently used in curries, soups, and stews.

Functional foods are gaining prominence in contemporary diets as lifestyle-related chronic diseases become more common, and such foods may help reduce associated risks. Incorporating moringa leaves into baked products has been shown to significantly enhance their nutrient profiles. For example, wheat flour bread fortified with 5% moringa leaf powder demonstrated notable increases in protein and crude fiber contents, by 54% and 56% respectively. Similarly, moringa-based functional teas contain high levels of phenolic compounds, highlighting the potential health benefits of integrating moringa into functional food products.

Ecological significance

Apart from its nutritional and medicinal value, the moringa tree holds significant ecological importance. It requires minimal water to grow, making it well suited for arid and drought-prone regions. This resilience has made moringa a preferred choice for reforestation efforts, soil improvement, and erosion control in areas with challenging environmental conditions. As concerns for environmental sustainability rise, the moringa tree emerges as a highly valuable resource.

Its deep root system helps prevent soil erosion and enhances soil fertility, while its rapid growth contributes to improved carbon sequestration. Its ability to thrive in adverse climatic conditions makes it suitable for reforestation and land restoration programs. Additionally, the tree provides habitat and food sources for various insects and animals, thereby supporting local biodiversity.

Prospective areas for future research

In recent years, modern science has increasingly focused on the moringa tree. There is a need for genomic studies and molecular breeding programs aimed at developing high-yielding, nutrient-dense varieties. The bioactive compounds found in various parts of the plant are being investigated for their therapeutic potential, offering promising avenues for pharmaceutical and nutraceutical applications. Researchers are also encouraged to explore moringa leaves as a key ingredient in functional foods.

Current studies are examining its potential role in managing chronic diseases such as diabetes, hypertension, and certain types of cancer. Large-scale human trials are required to determine the efficacy of moringa against different health conditions. There is also vast scope for developing value chains in moringa products, such as leaf-to-powder and leaf-to-tea processing.

While moringa offers an extensive range of benefits, its full potential has yet to be realized. Challenges, including limited awareness, inconsistent cultivation practices, and insufficient research funding, continue to hinder its widespread adoption. As climate change increasingly influences agricultural systems and global food security, the moringa tree presents a promising opportunity for sustainable and resilient food production.

SUMMARY

Moringa (*Moringa oleifera*) is a highly nutritious and multipurpose tree valued for its leaves, pods, and seeds, which are rich in vitamins, minerals, antioxidants, and essential amino acids. Its diverse phytochemicals including flavonoids, phenolic acids, and isothiocyanates contribute to its anti-inflammatory, antimicrobial, and antioxidant properties. Widely used in traditional medicine and functional foods, moringa supports immune health, metabolic regulation, and overall well-being. The tree thrives in arid climates, offering ecological benefits such as soil conservation and biodiversity enhancement. Despite its potential, further research, improved cultivation practices, and value-chain development are needed to fully harness its nutritional, medicinal, and environmental advantages.

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