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Moringa oleifera (Moringaceae): A Miracle Tree in Pharmacognosy

CHAPTER 3: Nutritional and Nutraceutical Significance

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Abstract:

Moringa oleifera commonly termed as the "miracle tree" is also known for its abundant phytochemical characteristics and various therapeutic uses. It has drawn a lot of global recognition as a highly nutrient dense, useful plant with substantial nutraceutical potential. This plant is a remarkable resource for nutritional supplementation and the production of nutritious food because its many parts, particularly its leaves, are rich in proteins, essential amino acids, minerals, vitamins, fibres, carotenoids, and antioxidant phytochemicals, which encourage its application in the management and prevention of nutrition linked disorders. In addition to its nutritional benefits, *Moringa oleifera* possesses important nutraceutical properties as it contains phytochemicals such as flavonoids, alkaloids phenolics, saponins, glucosinolates and tannins. These phytochemicals components have strong antiproliferation, anti-inflammatory, hepatoprotective, antiatherosclerotic, antinociceptive, oxidative DNA damage protective, antidiabetic, antiperoxidative and cardioprotective. *M. oleifera* containing dietary supplements and food items are advised as "novel food" preparations that promote health. Consuming *Moringa*-based products on a regular basis has been linked to enhanced immunity, better metabolic health, and protection against disorders caused by oxidative stress.





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This chapter explores the nutritional profile of *M. oleifera*, along with its nutritional and nutraceutical applications, health-promoting benefits, safety considerations, and future potential in food science and human health. *Moringa oleifera* has become an important plant for sustainable nutrition and public health promotion because of its low cost, ease of cultivation, and widespread adaptation in tropical and subtropical countries. It is promising as a natural nutraceutical for the prevention and management of several chronic diseases as evidenced by mounting scientific data demonstrating its nutritional and therapeutic effects.

Keywords: *M. oleifera*, antiperoxidative, antiproliferation, immunity and nutritional.

1. Introduction:

The "miracle tree," *Moringa oleifera* has become well-known for its valuable nutritional composition and extensive therapeutic capacity. It highlights the variety of bioactive secondary metabolites that support its diverse medicinal activities, including flavonoids, alkaloids, isothiocyanates, phenolic acids, saponins, and glucosinolates. The chapter emphasizes its expanding use in functional foods, dietary supplements, and cosmeceutical products in addition to its medical uses, indicating its commercial and industrial significance (1). Although *Moringa oleifera* is thought to be native to Bangladesh, Afghanistan, India, and Pakistan, it grows in practically every tropical and subtropical region on Earth. Studies show that *M. oleifera* is among the most reliable and reasonably priced alternatives for good nutrition. Every section of the plant was found to contain bioactive components. The leaves of *M. oleifera* are abundant in calcium, minerals, potassium and beta-carotene. The tree's bark is supposed to be extremely helpful in treating a range of conditions, including toothaches, hypertension, and ulcers. However, it has also been found that roots can be used to treat helminthiasis, paralysis, and toothaches. The tree is believed to offer amazing qualities for alleviating malnutrition in newborns and lactating mothers (2). *M. oleifera* carries numerous nutritious and bioactive compounds and has been utilized for ages in Ayurvedic and Unani medicinal systems. Originally from the northern Indian sub-Himalayan plains, the tree is currently grown in tropical and subtropical climates worldwide. It is acknowledged as one of the most important plant species that is extensively grown in India and is a member of the *Moringaceae* family (3). The *Moringa* species has more calcium than milk, more iron than spinach, more potassium





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than bananas, more vitamin C than oranges, and more vitamin A than carrots, and a protein level comparable to that of milk. Numerous nutritional and therapeutic qualities have been documented for *M. oleifera's* root, leaves, flowers, bark, gum, seed, fruit pods, and seed oil.

In Nigeria, traditional medical practitioners utilize this plant to treat reproductive disorders in women and to boost male fertility. Over 90 nutritionally significant bioactive constituents, including vitamins, protein, lipids, carbohydrates, minerals, and dietary fibres, have been found in *M. oleifera*. As a result, it is utilized as a nutrient source in dietary supplements in tropical regions where malnutrition is a serious issue, particularly among children and newborns (4).

The number of publications on *Moringa oleifera* over the last ten years has shown extraordinary growth on a global basis. The leaves are rich in nutrients and medicinal components, have great growth potential, and are easy to collect and process. Additionally, the Chinese Health Department has listed *M. oleifera* leaf as a new food resource in 2012(5).

Depending on the location, cultivar, season, and several parts of *Moringa oleifera*-leaves, flowers, fruits, seed oil, pods, seeds, bark, and roots each contain a wide range of phytochemical components. This chapter explores how *M. oleifera* is used in various fields because of its well-known bioactive components, nutraceutical uses, and therapeutic applications (6).

2. Nutritional Composition

The leaves of *Moringa oleifera* are very rich in nutrients. Table 1 shows the composition and functions of dried *Moringa oleifera* leaf powder.

Table 1: Nutrient Composition and Functional Significance of Dried *Moringa oleifera* Leaf Powder

Components	Range (per 100 g dry weight)	Functional Significance
Fat	4.03–9.51 g	Low fat, rich in polyunsaturated fatty acids
Vitamin C	187.96–278.50 mg (fresh leaves)	Very high, antioxidant and enhances iron absorption





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Protein	22.99–29.36 g	High-quality plant protein, all essential amino acids
Crude fiber	6.00–9.60 g	Moderate fiber content
Calcium (Ca)	1.322–2.645 g	Important for bones, teeth, blood clotting
Carbohydrates	~47–56 g	Energy-rich
Ash (minerals)	8.05–10.38 g	High mineral content
Phosphorus (P)	0.152–0.304 g	Bone and energy metabolism
Potassium (K)	1.317–2.025 g	Electrolyte balance, blood pressure control

2.1 Leaves (Dried Powder)-Key Nutrients

Dried *M. oleifera* leaf powder is highly nutritious, containing abundant protein (22.99–29.36 g), low fat (4.03–9.51 g), moderate fiber (6.00–9.60 g), and significant carbohydrates (~47–56 g) that provide energy. It is also rich in minerals, including calcium (1.322–2.645 g) for bone strength, phosphorus (0.152–0.304 g) for energy metabolism, and potassium (1.317–2.025 g) for maintaining blood pressure, along with vitamin C (187.96–278.50 mg), a strong antioxidant. These nutritional components make Moringa an important functional food with potential roles in reducing malnutrition, promoting a good metabolic health, and supporting the prevention of chronic diseases (7).

2.2 Seeds

M. oleifera leaves and seeds are a significant source of protein; the bioavailability and content of essential amino acids determine the nutritional quality. *M. oleifera* seeds have a considerably greater protein content as compared to leaves.

It was found that seed powder contained a higher protein content than a number of legumes, including horse gram, cowpea, chickpea, and bambara bean (8).

High protein Moringa seed flour, which may be helpful in food technology and human nutrition, can be produced by removing the lipids present in Moringa seeds. The seeds





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exhibit anticancer, antibacterial, and anti-inflammatory properties against bacteria and fungi. *M. oleifera* seeds contain vitamin B1 and vitamin A; they also contain minerals, micronutrients, and bioactive compounds such as sterols, flavonoids, saponins, phytates, and trypsin inhibitors (9).

2.3 Flowers

Moringa oleifera flowers have long been a part of traditional diets and are also nutritionally significant. The flowers exhibit modest levels of carbs, minerals, and protein. Their antioxidant properties are attributed to their abundance of flavonoids and phenolic substances. Fresh flowers have a moisture content of 85 to 90% and a dry weight protein level of 3 to 4%. Additionally, the flowers have high concentrations of calcium, phosphorus, and vitamin C. Flowers of this plant are utilized in traditional medical treatments as well as salads and soups in some areas. The bioactive compounds found in the floral part, such as niazimicin and other isothiocyanates, have increased their potential for medicinal applications (10).

2.4 Pods (Drumsticks)

Moringa oleifera's pods, also known as "drumsticks," are widely consumed in many parts of Asian nations. Young, immature pods have a similar taste to green beans and are soft. On a fresh weight basis, the pods have about 75-80% moisture, 2-3% protein, 1-2% fat, and 12 -15% carbs. They are abundant in essential minerals including potassium, magnesium and calcium.

Furthermore, the pods provide substantial levels of vitamin C and vitamin A. It contains 2-3% fiber content, which promotes digestive health. Harder seeds from mature pods are extracted before cooking. Soups, curries, and vegetable recipes frequently use the fibrous pod walls (11).

2.5 Roots

Alkaloids found in the roots include moringine, which possesses stimulating qualities comparable to those of piperine from black pepper. Traditionally, root extract has been used to treat gastrointestinal issues, fever, and inflammation.





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In Ayurvedic medicine, roots are used as a general tonic and in small amounts to treat nerve disorders. The root can be mashed into a horseradish-tasting paste that has been used to treat malaria, toothaches, and snakebite. The root's antioxidant action is enhanced by flavonoids and phenolic substances (12).

2.6 Phytochemical and Bioactive Compounds

This plant contains several bioactive compounds, including flavonoids, Vitamins, isothiocyanates, phenolic acids, tannins, and saponins, which among the many bioactive components of this plant that are found in considerable quantities in different parts of the plant (13). Table 2 portrays main classes of bioactives of *M. olifera*.

Table 2: Major Classes of Bioactives (14)

Class	Key Compounds	Main Sources	Key Activities
Alkaloids	Various alkaloids	Leaves, roots	Antimicrobial, analgesic
Flavonoids	Quercetin, Kaempferol, Rutin, Myricetin	Leaves	Antioxidant, anti-diabetic, anti-cancer
Isothiocyanates	Glucomoringin, 4-(α -L-rhamnosyloxy) benzyl ITC	Seeds, leaves	Anti-inflammatory, antimicrobial, anticancer
Phenolic acids	Gallic acid, Chlorogenic acid, Caffeic acid	Leaves	Antioxidant, anti-inflammatory, anti-cancer
Tannins & Saponins	Tannins, saponins	Leaves, bark	Antioxidant, antimicrobial
Glucosinolates	Glucomoringin, glucosinolates	Seeds	Antioxidant, antihypertensive, anti-inflammatory





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Sterols	β -sitosterol	Seeds, stem	Anti-inflammatory, cardioprotective
Novel isolates	Niazimin A&B, Muramoside A&B	Leaves, seeds	Antioxidant, anticancer, antihypertensive, hepatoprotective

More than 100 bioactive compounds have been identified in *Moringa oleifera*, and its varied pharmacological activities are driven by the eight primary classes mentioned in Table 2. The main antioxidants in leaves are flavonoids (quercetin, kaempferol, rutin, and myricetin), which have strong anti-diabetic, anti-cancer, and free radical scavenging properties via blocking oxidative stress and inflammatory pathways. Gallic acid, chlorogenic acid, and caffeic acid are phenolic acids with anti-inflammatory and chemopreventive properties in addition to making a substantial contribution to the plant's antioxidant capacity. Moringa's potent anti-inflammatory, antimicrobial, and anticancer effects are caused by isothiocyanates, specifically glucomoringin and 4-(α -L-rhamnosyloxy) benzyl isothiocyanate, which are unique bioactives primarily found in seeds and leaves. These bioactives work by modulating NF- κ B and other inflammatory mediators (14). Glucosinolates, particularly glucomoringin, have antihypertensive, anti-inflammatory, and antioxidant properties and act as precursors to isothiocyanates. While tannins and saponins show antioxidant and antimicrobial activities through membrane disruption and free radical scavenging, alkaloids found in leaves and roots have antibacterial and analgesic qualities.

Seeds and stems contain sterols, especially β -sitosterol, which modulate cholesterol metabolism to provide anti-inflammatory and cardioprotective benefits. Most notably, new isolates exclusive to Moringa, such as niazimin A & B and muramoside A & B, have strong antioxidant, anticancer, antihypertensive, and hepatoprotective properties that are not present in other plant species (15).

3. Nutraceuticals and Pharmacological Activities





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Moringa oleifera's abundance of bioactive substances, including flavonoids (quercetin, kaempferol), phenolic acids (gallic acid, chlorogenic acid), isothiocyanates, and alkaloids, is responsible for its exceptional health benefits. Together, these phytochemicals help the body combat oxidative stress, lower inflammation, and neutralize dangerous free radicals. Moringa helps prevent several chronic illnesses, such as diabetes, cancer, high blood pressure, heart disease, and nerve disorders, through these processes.

More than 200 investigations have validated its therapeutic effects; improvements in blood sugar regulation, cholesterol levels, and antioxidant status have been demonstrated in both human and animal clinical trials. The main pharmacological actions of *Moringa oleifera* are explained in the following subsections, along with how they function and the health benefits they offer.

3.1 Antioxidant Activity

This plant has a high concentration of polyphenolic components, including flavonoids and phenolic acids, which are primarily responsible for its strong antioxidant potential. Free radicals are effectively neutralized by these compounds' hydroxyl groups, which supply electrons to stabilize reactive molecules.

Research has shown that both leaf and seed extracts exhibit strong ABTS, DPPH, -OH, and $O_2^{\cdot-}$ radical scavenging activities. Due to its antioxidant properties, Moringa can be used to produce functional meals and medicinal products that can help prevent diseases associated with oxidative stress (16).

3.2 Antidiabetic Properties

This plant has strong anti-diabetic properties via a variety of methods. The plant promotes the activity of antioxidant enzymes like catalase, superoxide dismutase, and glutathione while inhibiting the oxidative stress and inflammatory pathways.

In animal studies, leaf extracts administered at dosages of 100 to 300 mg/kg for two to eight weeks have shown beneficial effects on blood glucose control. Human clinical trials have demonstrated that consuming approximately 20g of leaf powder for at least 2 weeks improves postprandial glucose levels in individuals with diabetes and





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prediabetes. Furthermore, the plant reduces inflammatory markers elevated in diabetes, including IL- β , TNF- α , IL-6, MCP-1, and nitric oxide synthase (17).

3.3 Anticancer Activity

Several bioactive compounds found in *Moringa oleifera* have been demonstrated to have anticancer properties. Important compounds include β -sitosterol, niazimicin, niazirin, and 4-(α -L-rhamnosyloxy)-benzyl isothiocyanate. Research indicates that, ethanolic leaf extracts can kill about 82% of acute myeloid leukemia cells and 86% of acute lymphoblastic leukemia cells.

HepG2 liver cancer cells are 81% destroyed by hot water extracts. The plant exhibits potent anticancer-promoting activity, helping prevent the spread of cancer. These anticancer properties are attributed to the ability of *Moringa* compounds to induce cell death in cancer cells while protecting normal cells, making it a good option for cancer prevention strategies (18).

3.4 Hepatoprotective Effects

Moringa oleifera benefits the liver in several ways. Significant compounds like quercetin, gallic acid, kaempferol, and chlorogenic acid help prevent non-alcoholic fatty liver disease by reducing fat accumulation in liver cells.

The plant produces more proteins that break down lipids in order to prevent excessive fat formation. *Moringa's* hepatoprotective application makes it useful for both producing liver protective medication and promoting overall liver health. Additionally, the antioxidant activity helps protect liver cells from dangerous substances and oxidative stress (19).

3.5 Antimicrobial Activity

Moringa oleifera has antibacterial application against a range of bacterial species. Methanol, ethyl acetate, and ethanol leaf extracts have demonstrated antibacterial application against *Pseudomonas aeruginosa* and *Erwinia carotovora*, among other pathogenic microbes. The anti-bacterial activity is believed to be caused by bioactive compounds such as alkaloids, isothiocyanates, and flavonoids which can harm bacterial cell membranes and halt bacterial growth. A novel antimicrobial peptide produced from





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Moringa seed protein hydrolysates shows strong inhibitory effects on *Staphylococcus aureus* through irreversible membrane damage and enhanced membrane permeability. These properties indicate potential applications in the production of natural antibacterial products, as well as in supporting the traditional use of *moringa* to treat infections (20).

3.6 Wound Healing Activity

Moringa oleifera carries significant wound healing properties due to its bioactive components, which include quercetin, rutin, kaempferol, gallic acid, rosmarinic acid and chlorogenic acid. These compounds promote wound healing by reducing oxidative stress at the wound site and accelerating skin tissue regeneration.

Research has shown that plant extracts can help fasten the healing of cutaneous wounds, and they have traditionally been used to treat wounds and skin injuries.

The anti-inflammatory and antioxidant properties of this plant compounds promote improved wound healing and reduced inflammation (21).

3.7 Neuroprotective Effects

Moringa oleifera's antioxidant application may offer protection against neurological disorders like depression, Alzheimer's disease, multiple sclerosis, and neuropathic pain. The ethanol extract of *Moringa* leaves releases gamma-aminobutyric acid, or GABA, which functions as an anticonvulsant to treat epilepsy.

The bioactive compounds help in the protection of brain cells from inflammation and oxidative damage, two major contributors to neurodegenerative disorders. These neuroprotective properties suggest the possible uses for *Moringa* in management of neurological conditions and support brain health (22).

3.8 Cardiovascular Protection

There are several ways that *moringa oleifera* protects the heart. Quercetin, one of the primary components of *moringa*, which lowers cholesterol and inflammation to protect cardiovascular health. Alkaloids from the plant help lower fat and cholesterol levels, prevent hyperlipidemia, and restore normal blood pressure. Because of its





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cardioprotective properties, *moringa* can help in the prevention of cardiovascular diseases and maintain healthy blood pressure and cholesterol profiles (23).

3.9 Anti-inflammatory Properties

Moringa oleifera has significant anti-inflammatory properties because to its high content of polyphenols, flavonoids, and other bioactive compounds. The plant reduces inflammation by inhibiting pro-inflammatory cytokines such as TNF- α , IL-6 and IL- β . Studies have demonstrated that *moringa* leaf extract can reduce the pain, redness, and fluid swelling in conditions like rheumatoid arthritis. Because moringa compounds can reduce oxidative stress, which leads to inflammation, and block inflammatory pathways, they are believed to have anti-inflammatory properties. This application of the plant supports the traditional use of *moringa* to treat inflammatory conditions and joint discomfort (24).

3.10 Anti-ulcer Activity

Moringa oleifera has been shown to prevent stomach ulcers. The plant's antioxidant and anti-inflammatory attributes protect the stomach mucosa from damage. Traditional medicine has utilized moringa to treat ulcers, and studies have indicated that it can help prevent the formation of new ulcers as well as fasten the healing of existing ones. The bioactive components of moringa strengthen the stomach's lining and reduce the production of gastric acid, shielding the stomach from substances that can cause ulcers (25).

4. Conclusion

Moringa oleifera represents one of the most valuable multifunctional plants with exceptional therapeutic and nutritional significance. This chapter methodically studied this amazing plant's complete nutritional and nutraceutical applications, including its botanical traits, traditional uses, comprehensive nutritional composition across all plant parts, bioactive compounds, and a range of pharmacological properties.

The nutritional analysis indicates that *Moringa oleifera* is a complete food source that contains high quality of proteins with all the essential amino acids, plenty of vitamins





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like A, C, and B-complex, important minerals like magnesium, calcium, potassium, zinc and iron, as well as significant amounts of dietary fiber and healthy fats.

Flavonoids like quercetin, kaempferol, and rutin; phenolic acids like chlorogenic acid, gallic acid, and caffeic acid; isothiocyanates; alkaloids, tannins, saponins, carotenoids, and glucosinolates are *among* the bioactive substances found in *Moringa oleifera*. These bioactive components work synergistically to create the plant's remarkable therapeutic effects through several processes and mechanisms involving anti-inflammatory responses, antioxidant activity, and cellular modulation.

In conclusion, *Moringa oleifera* is an excellent example of a natural resource that could concurrently address several of the global health issues. It is an essential tool in the battle against malnutrition because of its wide range of pharmacological properties that may help prevent and treat numerous chronic diseases.

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