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A Review on Various Medicinal Aspects of *Moringa oleifera* Lam.

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Abstract : *Medicinal plants have been the backbone of traditional healthcare for centuries, and many modern drugs can still be traced back to a plant source. Moringa oleifera Lam. (family Moringaceae), commonly called the drumstick tree or horseradish tree, is one of the most widely discussed plants in this context. Almost every part of the tree, including the leaves, pods, seeds, flowers, bark and roots, has been used in Ayurveda, Unani and other folk systems for treating a long list of complaints ranging from fever and wounds to diabetes and inflammation. The plant is also unusually rich in nutrients, with high levels of protein, vitamins A and C, calcium, iron and potassium in its leaves and pods.*

Phytochemical studies have reported glucosinolates, isothiocyanates, flavonoids (quercetin, kaempferol), phenolic acids (chlorogenic acid, gallic acid), alkaloids, tannins, saponins and sterols. The isothiocyanate called moringin and the glucosinolate glucomoringin are considered characteristic of the genus. Experimental work in cell lines and animals has shown antidiabetic, antioxidant, anti-inflammatory, antimicrobial, anticancer, hepatoprotective, cardioprotective, neuroprotective, wound healing, antiulcer, analgesic and immunomodulatory effects. A handful of small human trials point towards benefit in blood glucose control and lactation, although the clinical evidence is still thin.

This review brings together the botanical features, traditional uses, nutritional value, phytochemistry, pharmacological activities, safety profile and future prospects of Moringa oleifera, mainly from literature published over the last two decades. The aim is to give a clear picture of what is established, what is only suggested, and where more work is needed..

Keywords: Moringa oleifera; drumstick tree; phytochemistry; pharmacological activity; antidiabetic; antioxidant; traditional medicine; nutraceutical.

I. INTRODUCTION

Plants are not just a source of food. For most of human history they were the only source of medicine, and even now the World Health Organization estimates that a large share of people in developing countries depend on traditional medicine, mostly plant-based, for primary healthcare. In India this knowledge has been written down in classical texts such as the Charaka Samhita and Sushruta Samhita, and it is still alive in households where a kadha or a leaf paste is the first thing tried when someone falls ill.

The interest in plant drugs is not only cultural. Aspirin came from willow bark, digoxin from foxglove, vincristine from the Madagascar periwinkle, and paclitaxel from the Pacific yew. Because of this track record, researchers keep returning to traditionally used plants to look for new lead molecules, and also for safer, cheaper supplements that can be taken along with conventional treatment.

Among these plants, *Moringa oleifera* has attracted unusual attention. It is a fast-growing, drought-tolerant tree native to the sub-Himalayan foothills of north-western India, and it is now grown across tropical and subtropical regions of Asia, Africa and Latin America. In Indian kitchens the long green pods are known as drumsticks (shevga in Marathi, saijan or sahjan in Hindi) and go into sambar and curries, while the leaves are cooked as a vegetable or dried into powder. Because the tree grows on poor soil, needs little water and gives edible material almost all year, it has been

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promoted by several international agencies as a tool against malnutrition, which is why it earned names such as "miracle tree" and "tree of life".

The popularity of Moringa has also brought a lot of exaggerated claims, particularly on the internet and in the supplement market. A responsible review has to separate three things:

what the traditional literature says, what laboratory and animal studies have actually shown, and what has been confirmed in humans. This article tries to keep those three levels apart. It covers the botany of the plant, its traditional uses, nutritional composition, the major classes of phytoconstituents, the reported pharmacological activities, toxicity and safety data, and the gaps that still need to be filled.

Aim and Scope of the Review

The aim of this work is to compile and critically summarize the available information on the medicinal aspects of *Moringa oleifera*. Original research papers, earlier reviews and standard pharmacognosy texts were consulted. Search terms included *Moringa oleifera*, drumstick, phytochemistry, antidiabetic, antioxidant, toxicity and clinical trial, using databases such as PubMed, ScienceDirect, Google Scholar and Scopus.

Botanical Profile

Taxonomical Classification

Rank	Name
Kingdom	Plantae
Division	Magnoliophyta
Class	Magnoliopsida
Order	Brassicales
Family	Moringaceae
Genus	*Moringa*
Species	*Moringa oleifera* Lam.

The family Moringaceae has only one genus, *Moringa*, with about 13 species. These range from slender herbs and shrubs to massive bottle-shaped trees, and *M. oleifera* and *M. stenopetala* are the two most useful ones. Of the 13, *M. oleifera* is by far the most widely cultivated and the best studied.

Vernacular Names

Language	Name
English	Drumstick tree, Horseradish tree, Ben oil tree
Marathi	Shevga
Hindi	Sahjan, Saijan, Munga

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Sanskrit	Shigru, Sobhanjana
Gujarati	Saragvo
Tamil	Murungai
Telugu	Mulaga
Kannada	Nugge
Language	Name
Bengali	Sajina
Unani	Sahajna

Macroscopic Description

Moringa oleifera is a small to medium-sized deciduous tree, usually 5 to 10 metres tall, though it can reach 12 metres if left alone. The trunk is short and often crooked, with soft, spongy wood and pale grey, corky bark that peels off in thin strips. The branches are drooping and brittle, so the crown looks open and umbrella-like.

Leaves: Leaves are alternate, bipinnate or tripinnate, 20 to 70 cm long, with small oval leaflets (1 to 2 cm) arranged in opposite pairs. They are thin and bright green and fall easily in the dry season.

Flowers: Flowers are fragrant, creamy white to pale yellow, about 2.5 cm across, and borne in drooping axillary panicles. They are bisexual and zygomorphic, with five unequal petals, five reflexed sepals and five stamens. The tree may flower once or twice a year, depending on climate, and in southern India it can flower almost throughout the year.

Fruit (pod): The fruit is a long, three-sided, pendulous capsule, 20 to 60 cm in length, which splits lengthwise into three parts when mature. Young pods are green and tender and are the part eaten as a vegetable, while mature pods become woody and brown.

Seeds: Each pod holds around 12 to 35 round seeds, dark brown, about 1 cm wide, with three papery white wings. The seeds are the source of ben oil.

Roots: The tap root is thick and tuberous in young plants and has a sharp, pungent smell and taste that resembles horseradish, which is how the English name arose.

Distribution and Cultivation

The tree is native to India, particularly the foothills of the Himalayas in Uttar Pradesh, Bihar and neighbouring regions, and to parts of Pakistan, Bangladesh and Afghanistan. Today it is cultivated in the Philippines, Thailand, Sri Lanka, many African countries, the Caribbean and parts of South America. India is among the largest producers, with Tamil Nadu, Karnataka, Andhra Pradesh and Maharashtra being important growing states.

Moringa grows best in warm, dry to semi-arid climates with temperatures of about 25 to 35 °C, and it tolerates poor soil and drought quite well. It does not like waterlogging or frost. It is propagated through seeds or hardwood cuttings and can begin to produce pods within 6 to 12 months of planting. For leaf production, farmers often grow it at high density and cut it back repeatedly, which gives several harvests in a year.

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Microscopic and Physicochemical Features

Transverse sections of the leaf show a single-layered epidermis covered by a thin cuticle, with anomocytic stomata on both surfaces. The mesophyll is differentiated into palisade and spongy parenchyma, and calcium oxalate crystals are scattered in the tissue. The stem bark shows cork cells, a wide cortex with stone cells and a secondary phloem with medullary rays. The root shows a thick cork layer, a prominent xylem region and starch grains in the parenchyma.

Standard pharmacognostic parameters reported for the leaf powder include moisture content of roughly 5 to 10 per cent, total ash of about 8 to 12 per cent and acid-insoluble ash well below 2 per cent. These values vary with the place of collection and the stage of maturity, so they should be regarded as approximate and not as fixed pharmacopoeial limits.

Traditional and Ethnomedicinal Uses

In Ayurveda, Moringa (Shigru) is described as having pungent and bitter taste (katu, tikta rasa), hot potency (ushna virya) and a pacifying effect on kapha and vata. Classical texts recommend it for swelling, abscesses, worm infestation, tumours, and disorders of the eye and spleen. In Unani medicine, the plant is used as a stimulant, diuretic and aphrodisiac. Outside India, people in the Philippines, West Africa and the Caribbean use leaf preparations for anaemia, to improve breast milk and to manage high blood pressure and sugar.

Plant part	Traditional use
Leaves	Anaemia, diabetes, hypertension, wounds, headache, fever, to increase breast milk, eye problems
Pods (drumsticks)	Intestinal worms, liver and spleen disorders, joint pain, diarrhoea
Plant part	Traditional use
Seeds	Water purification, arthritis, rheumatism, gout, skin diseases, cramps
Seed oil (ben oil)	Skin ailments, hair and skin care, massage for joint pain, base for perfumes
Flowers	Cold, cough, tonic, aphrodisiac, to treat inflammation and muscle disease
Bark	Digestive problems, toothache, snake bite poultice, abortifacient (folk use)
Roots	Rheumatism, stimulant, diuretic, cardiac tonic, antifertility, abscess
Gum	Dental caries, asthma, rheumatic pains

It is worth noting that a few of these uses, such as the abortifacient use of root and bark, are linked with real safety concerns, and these are discussed later in the article.

An interesting practical use, beyond medicine, is the seed powder as a natural coagulant. The cationic proteins in the seeds bind to suspended particles and bacteria in turbid water and make them settle. This has been tested for household water treatment in rural areas where chemical coagulants are not easily available.

Nutritional Composition

The nutritional profile is the main reason the plant has been promoted for public health. The leaves are particularly dense in nutrients, and the pods are a good source of fibre and vitamin C. The values below are approximate, because they change with variety, soil, season and drying method.

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Nutrient (per 100 g)	Fresh leaves	Dried leaf powder	Fresh pods
Energy (kcal)	64	205	37
Protein (g)	6.7	27	2.1
Fat (g)	1.7	2.3	0.2
Carbohydrate (g)	12.5	38	8.5
Nutrient (per 100 g)	Fresh leaves	Dried leaf powder	Fresh pods
Fibre (g)	0.9	19	3.2
Calcium (mg)	440	2003	30
Iron (mg)	0.85	28	0.36
Potassium (mg)	259	1324	461
Vitamin A, as beta-carotene (mg)	6.8	16	0.1
Vitamin C (mg)	220	17	141

The protein in the leaves contains all the essential amino acids, including methionine and cysteine, which are low in many other vegetable sources. The leaves also carry B-complex vitamins, vitamin E and a good amount of minerals such as magnesium, zinc and phosphorus. Seeds are rich in oil (30 to 40 per cent), with oleic acid making up more than 70 per cent of the fatty acids. This high oleic content gives ben oil good oxidative stability, which is why it was once used in watch-making and in the cosmetic industry.

It should be remembered, however, that dried leaf powder is a concentrated food, and the numbers per 100 g do not mean that a person actually eats that quantity. A realistic daily serving of 5 to 10 g will contribute much less than the table suggests. The leaves also contain anti-nutritional factors such as phytates, oxalates and tannins, which can reduce the absorption of minerals like iron and calcium to some extent.

Phytochemistry

Moringa is chemically quite interesting because it contains an unusual combination of compounds. Along with the usual plant phenolics and flavonoids, it contains glucosinolates and isothiocyanates, which are otherwise typical of the mustard family (Brassicaceae) and are not common in other tropical trees. This is not surprising when one remembers that the order Brassicales includes both families.

Glucosinolates and Isothiocyanates

The main glucosinolate in Moringa is glucomoringin (4-(alpha-Lrhamnopyranosyloxy)benzyl glucosinolate). When the plant tissue is crushed or chewed, the enzyme myrosinase comes into contact with the glucosinolate and hydrolyses it into the corresponding isothiocyanate, **moringin** (4-(alpha-L-rhamnopyranosyloxy)benzyl isothiocyanate). Moringin is relatively stable for an isothiocyanate and has been linked with anti-inflammatory, anticancer, antidiabetic and

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neuroprotective effects. Other related compounds include niazirin, niazirinin and niazimicin, the last one being a thiocarbamate that has shown chemopreventive potential in some experimental models.

The seeds contain the highest concentration of glucomoringin, while leaves contain lower amounts, mixed with other glucosinolates such as the acetylated rhamnosyl forms. Since cooking and drying inactivate myrosinase, the amount of active isothiocyanate that a person gets depends a lot on how the plant is prepared.

Flavonoids and Phenolic Compounds

The leaves are a rich source of flavonoids, mainly flavonols occurring as glycosides. The principal ones are quercetin-3-O-glucoside, quercetin-3-O-(6"-malonyl)-glucoside, kaempferol glycosides and isorhamnetin. Phenolic acids reported include chlorogenic acid, gallic acid, ellagic acid, ferulic acid and caffeic acid. Chlorogenic acid is often present in notable quantity and is thought to contribute to the glucose-lowering effect. Total phenolic content in leaf extracts depends heavily on the solvent and is generally highest in aqueous ethanol or methanol extracts.

Alkaloids, Tannins, Saponins and Others

Moringine and moringinine (reported as benzylamine-type alkaloids) were isolated from roots and bark, although some later work has questioned the exact structures. Pterygospermin, an antibacterial compound, was reported from roots and was initially credited for much of the antimicrobial activity of the plant, but its role is still debated. Preliminary screening of extracts also shows tannins, saponins, terpenoids, sterols (betasitosterol, stigmasterol, campesterol) and cardiac glycosides. Carotenoids such as betacarotene, lutein and zeaxanthin are abundant in the leaves, giving them the dark green colour.

Summary of Important Phytoconstituents

Class	Examples	Main part	Reported activity
Glucosinolates	Glucomoringin	Seeds, leaves	Precursor of moringin
Isothiocyanates	Moringin	Seeds (after hydrolysis)	Anti-inflammatory, anticancer, antidiabetic
Class	Examples	Main part	Reported activity
Thiocarbamates	Niazimicin, niaziminin	Leaves, pods	Chemopreventive, antihypertensive
Flavonoids	Quercetin, kaempferol, isorhamnetin	Leaves, flowers	Antioxidant, antiinflammatory, hypoglycaemic
Phenolic acids	Chlorogenic, gallic, ferulic acid	Leaves	Antioxidant, hypoglycaemic
Alkaloids	Moringine, moringinine	Root, bark	Cardiac and sympathomimetic action
Sterols	Beta-sitosterol, stigmasterol	Leaves, seeds	Lipid-lowering
Carotenoids	Beta-carotene, lutein	Leaves	Provitamin A, antioxidant
Fatty acids	Oleic acid, behenic acid	Seed oil	Nutritive, emollient
Proteins	MO2.1 and other cationic peptides	Seeds	Antimicrobial, coagulant

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Extraction and Analytical Methods

Extraction methods commonly used for Moringa include maceration, Soxhlet extraction, ultrasound-assisted and microwave-assisted extraction. Methanol, ethanol, aqueous ethanol and water are the usual solvents. For glucosinolates, the extraction is done in hot methanol or boiling water to deactivate myrosinase first, and then the compounds are determined by HPLC. Phenolics and flavonoids are generally profiled by HPLC-DAD or LCMS, while total phenolics and total flavonoids are estimated spectrophotometrically with the Folin-Ciocalteu and aluminium chloride methods respectively. Standardization of commercial products is still a problem, because most do not state the marker compound they were standardized against.

Pharmacological Activities

A large number of in vitro and in vivo studies have been carried out on different extracts of *Moringa oleifera*. In this section the activities are discussed one by one. For most of them the evidence comes from cell lines or rodents, and this should be kept in mind while reading, because a result in a rat does not always translate to a patient.

Antidiabetic Activity

Diabetes mellitus is probably the most studied therapeutic area for Moringa. Aqueous leaf extract given orally to streptozotocin-induced diabetic rats reduced fasting blood glucose and improved glucose tolerance in several independent studies (Ndong et al., 2007; Jaiswal et al., 2009). In the study by Jaiswal and co-workers, treatment with the aqueous leaf extract lowered blood glucose and also improved haemoglobin and total protein levels in the treated animals. Similar results have been seen with pod and seed extracts.

The proposed mechanisms are several. Isothiocyanates and flavonoids may improve insulin sensitivity and increase glucose uptake in muscle and fat cells. Quercetin and chlorogenic acid are believed to inhibit intestinal alpha-glucosidase, which slows down carbohydrate digestion. Some reports also suggest protection of pancreatic beta cells from oxidative damage and a mild insulin-like action of certain leaf components (Mbikay, 2012).

Human data are limited but encouraging. A few small trials in type 2 diabetic and healthy volunteers found that 4 to 8 g of leaf powder daily lowered postprandial glucose by a modest amount. The sample sizes were small and the trial periods short, so Moringa cannot be called a replacement for standard antidiabetic drugs. At best it appears to be a useful adjunct, and patients who are already on insulin or sulfonylureas should be careful about the risk of low blood sugar.

Antioxidant Activity

Oxidative stress is involved in diabetes, cancer, atherosclerosis and neurodegeneration, so the antioxidant capacity of the plant gets a lot of attention. Leaf extracts show strong activity in DPPH and ABTS radical scavenging, ferric reducing power (FRAP) and lipid peroxidation assays, and the activity correlates well with total phenolic and flavonoid content (Sreelatha and Padma, 2009). Methanolic and aqueous ethanol extracts usually perform better than water extracts in chemical assays.

In animals, Moringa treatment increased the levels of endogenous antioxidant enzymes such as superoxide dismutase, catalase and glutathione peroxidase, and reduced malondialdehyde, a marker of lipid peroxidation. Chumark and colleagues (2008) reported both in vitro and ex vivo antioxidant effects of the leaf water extract, along with a reduction in cholesterol and in the size of atherosclerotic plaques in cholesterol-fed rabbits. It is likely that part of the benefit seen in other disease models is simply a consequence of this antioxidant action.

Anti-inflammatory and Analgesic Activity

Extracts of leaves, roots and seeds reduced carrageenan-induced paw oedema in rats in a dose-dependent manner, which is the standard screening model for acute inflammation. Isothiocyanates, especially moringin, appear to be the key players. In cultured macrophages, they suppress the production of nitric oxide, TNF-alpha, IL-1 beta and IL-6, and

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they act partly by inhibiting the NF-kappa B pathway and by activating the Nrf2 antioxidant response pathway. Seed extracts also reduced inflammation in a model of allergic airway disease in guinea pigs, which supports the traditional use of the seed for asthma.

Analgesic effects have been demonstrated through the acetic acid-induced writhing test and the hot plate test in mice. These results fit with the folk use of leaves and roots for headache and joint pain. There are no well-designed human trials on pain.

Antimicrobial Activity

Caceres and co-workers (1991) published one of the early reports showing that fresh leaf juice and seed extracts inhibit several bacteria, notably *Staphylococcus aureus* and *Pseudomonas aeruginosa*. Later studies tested extracts against *Escherichia coli*, *Bacillus subtilis*, *Salmonella typhi*, *Vibrio cholerae* and *Klebsiella pneumoniae*, and against fungi like *Candida albicans* and *Aspergillus niger*. The activity is usually moderate, with zones of inhibition smaller than those of standard antibiotics.

Two groups of compounds seem responsible. The isothiocyanates are reactive electrophiles that damage microbial cell membranes and interfere with enzymes, while the cationic seed proteins can bind to the negatively charged surface of bacterial cells. Pterygospermin was historically credited for the antibacterial effect of the root, but this needs fresh confirmation with modern methods. Seed powder has also shown the ability to remove bacteria from drinking water through flocculation, which links the water treatment use to the antimicrobial property.

Antiviral and antiparasitic properties have also been reported, including activity against herpes simplex virus and Epstein-Barr virus antigen activation in cells, and anthelmintic action against earthworms and some nematodes, matching the traditional use of the pods for worms.

Anticancer Activity

The anticancer potential of Moringa has been examined mainly in cell lines. Seed and leaf extracts reduced the viability of breast, colon, pancreatic, lung and liver cancer cells, mostly by inducing apoptosis and arresting the cell cycle (Abdull Razis et al., 2014). Niazimicin was found to suppress tumour promotion in a mouse skin model, and moringin has been linked to the induction of detoxifying phase II enzymes like quinone reductase, an effect typical of isothiocyanates from cruciferous vegetables. There is also a suggestion that Moringa may help reduce the toxicity of chemotherapy drugs like cisplatin.

It must be said plainly that there is no clinical proof that Moringa treats or prevents cancer in humans. The concentrations that kill cancer cells in a dish are often much higher than what could be reached in the blood after eating the plant, and this is a common problem with natural product research.

Hepatoprotective Activity

Leaf and seed extracts protected rat liver from damage caused by carbon tetrachloride, paracetamol, antitubercular drugs (isoniazid, rifampicin and pyrazinamide) and alcohol. Treated animals showed lower serum levels of ALT, AST and alkaline phosphatase and less histological damage. Hamza (2010) found that seed extract reduced liver fibrosis in rats and improved antioxidant status. The effect is attributed mainly to the antioxidant flavonoids and phenolics, and in some studies it was comparable to silymarin, the standard hepatoprotective agent used as a reference.

Cardiovascular, Antihypertensive and Hypolipidaemic Activity

The thiocarbamate and isothiocyanate glycosides, such as niazimicin and niaziminin, are linked to the blood pressure lowering effect that was seen with leaf extracts in rats, possibly via calcium channel blocking. Leaf, flower and root extracts produced lowering of total cholesterol, LDL, VLDL and triglycerides in animals fed high-fat diets, while HDL was either increased or unchanged. The beta-sitosterol content may add to this by interfering with cholesterol absorption. Cardioprotective effects have also been shown against isoproterenol-induced myocardial injury in rats. In

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clinical terms, a few small studies in postmenopausal women and in healthy volunteers reported modest improvements in lipid profile, although this is not yet strong enough to support any recommendation.

Neuroprotective and CNS Activity

Leaf extract improved memory and reduced oxidative damage in the brain in rodent models of Alzheimer's disease, partly by altering the levels of brain monoamines (Ganguly and Guha, 2008). Neuroprotective action has also been reported in models of Parkinson's disease, cerebral ischaemia and stress. Anxiolytic, antidepressant and anticonvulsant effects have been seen in mice. The mechanisms proposed are antioxidant action, inhibition of acetylcholinesterase and reduction of neuroinflammation. These are interesting but remain at the preclinical stage.

Wound Healing Activity

Topical application of leaf extract or aqueous paste to excision and incision wounds in rats increased wound contraction, collagen content and tensile strength, and the epithelialization period was shorter than in control animals. The antimicrobial and antioxidant properties likely help by keeping the wound clean and limiting oxidative damage, while the proteins and vitamin C in the leaf may assist collagen synthesis. This matches well with the folk practice of applying crushed leaves to cuts.

Antiulcer and Gastroprotective Activity

In rats, leaf and root extracts reduced gastric ulcers induced by aspirin, ethanol and pyloric ligation. They lowered gastric acidity and ulcer index and raised mucus protection. Antidiarrhoeal and spasmolytic effects have been described as well, which suits the traditional use of pods and leaves in digestive complaints.

Immunomodulatory Activity

Aqueous and ethanolic extracts increased antibody titre, delayed type hypersensitivity response and phagocytic activity in mice, indicating stimulation of both humoral and cellmediated immunity. At the same time, the strong anti-inflammatory effect shows that the plant may act as a modulator, and not just a stimulant, depending on the dose and the condition.

Galactagogue (Lactation Enhancing) Activity

In many Asian and African communities, Moringa leaves are given to nursing mothers to increase milk. A few small human studies from the Philippines and elsewhere reported higher breast milk volume in mothers who took leaf preparations when compared with controls (Estrella et al., 2000). The mechanism is not clear, but it may involve phytosterols and the high nutrient content. As the trials are small, further confirmation is needed.

Other Reported Activities

Several other effects have been described. Moringa has shown a protective role against anaemia in animals, which fits with its iron content, although the bioavailability of that iron is limited. Antiurolithiatic (anti-kidney stone) action has been seen in rats treated with root bark extract. Anti-asthmatic, antispasmodic, diuretic, antifertility and radioprotective activities have also been reported. Moringa seed oil is used in cosmetics for its emollient effects, and the leaves show UV-protective and anti-ageing potential in skin cell models.

Summary of Pharmacological Studies

Activity	Part used	Model	Main finding
Antidiabetic	Leaf, pod, seed	STZ-diabetic rats, small human trials	Lower blood glucose, improved tolerance
Antioxidant	Leaf, seed	DPPH, FRAP, rat models	Strong radical scavenging, higher SOD and catalase
Antiinflammatory	Leaf, seed, root	Paw oedema, macrophages	Reduced oedema, NO and cytokines

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Antimicrobial	Leaf, seed, root	Agar diffusion, MIC	Moderate activity against bacteria and fungi
Anticancer	Seed, leaf	Cancer cell lines, mouse skin	Apoptosis, phase II enzyme induction
Hepatoprotective	Leaf, seed	CCl4, paracetamol rat models	Lower ALT and AST, better histology
Hypolipidaemic	Leaf, flower	High-fat diet rats	Reduced cholesterol and triglycerides
Activity	Part used	Model	Main finding
Neuroprotective	Leaf	Rodent AD and PD models	Improved memory, less oxidative stress
Wound healing	Leaf	Excision and incision wounds in rats	Faster contraction, more collagen
Antiulcer	Leaf, root	Aspirin and ethanol ulcer models	Lower ulcer index
Galactagogue	Leaf	Small human trials	Increased milk volume

Mechanisms of Action in Brief

When all these reports are read together, a few common threads appear. First, the antioxidant effect, produced by flavonoids, phenolic acids and carotenoids, probably explains a good part of the hepatoprotective, neuroprotective and cardioprotective actions. Second, isothiocyanates activate the Nrf2 pathway, which switches on the cell's own antioxidant and detoxification genes, and at the same time they block NF-kappa B, which drives inflammation. Third, the glucose-lowering effect looks like a mix of alphaglucosidase inhibition, improved insulin sensitivity and protection of beta cells. Finally, the antimicrobial action depends on membrane damage caused by electrophilic isothiocyanates and cationic proteins.

Because one plant contains dozens of active compounds, the result in the body is usually the sum of many small effects instead of one strong, targeted action. This is both the strength of herbal medicine, in that it works through several routes, and its weakness, because it is harder to standardize and to predict.

Toxicity and Safety Profile

Moringa leaves and pods have been eaten for generations without obvious harm, and this is often taken as proof of safety. But food use and concentrated supplement use are not the same thing, and a few cautions are needed.

Acute and Sub-chronic Toxicity

Awodele and co-workers (2012) tested the aqueous leaf extract in rats and found the oral LD50 to be above 6400 mg/kg, which means the extract is practically non-toxic after a single dose. In the same work, sub-chronic dosing showed some changes in liver enzymes and kidney markers at high doses and some histological changes in the liver and kidney at the upper dose, so long-term safety at large doses cannot be taken for granted. Asare and colleagues (2012) studied supra-supplementation levels and reported effects on the liver, kidney and haematological parameters at very high doses, along with signs of DNA damage in a cell test using an aqueous extract. Stohs and Hartman (2015) reviewed the safety data and concluded that leaves appear safe at moderate doses, with limited concern from animal studies and few reports of adverse effects in humans.

Parts of the Plant Needing Caution

The root and bark contain alkaloids such as moringine and a compound called spirochin, which is a neurotoxin in higher amounts, and there are reports of uterine stimulation that gave the folk abortifacient use. For this reason, root and bark preparations should not be used, and pregnant women should avoid them completely. The seed contains some

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compounds that can be irritant when taken at high dose. Leaf extracts may also contain antinutritional compounds, and excess consumption of leaf powder has been linked in a few reports to gastric upset, loose stools and bloating.

Herb-Drug Interactions

There are no large clinical studies on interactions, but some points can be predicted from the pharmacology:

- **Antidiabetic drugs:** possible additive glucose-lowering effect, with a risk of hypoglycaemia.
- **Antihypertensives:** possible additive blood pressure reduction.
- **Levothyroxine:** goitrogenic glucosinolates and the possibility of interference with thyroid function have been mentioned, so thyroid patients should be careful.
- **CYP450 substrates:** experimental data suggest Moringa extracts can inhibit CYP3A4 and CYP2C9, and this could raise the level of drugs metabolized by these enzymes. This is largely based on in vitro and animal findings.
- **Anticoagulants:** the vitamin K content of leaves could theoretically oppose warfarin, although this has not been documented in a proper study.

Recommendations

Based on the present data, pregnant women and nursing mothers should consult a doctor before taking concentrated supplements (leaf as food is a different matter), and root or bark products should be avoided. People taking medicines for diabetes, blood pressure or thyroid disease should inform their physician before starting a Moringa supplement. A reasonable intake of leaf powder in studies has been 2 to 8 g a day, but there is no official recommended dose.

Clinical Evidence

Compared with the large amount of preclinical work, clinical studies are few and mostly small. Table 4 lists the main areas where human data exist.

Area	Design	Dose of leaf	Outcome
Blood glucose	Small trials in healthy and type 2 diabetic subjects	4 to 8 g/day	Modest lowering of postprandial glucose
Lactation	Randomized trials in mothers of preterm infants	Capsules or leaf preparations	Increase in milk volume in some studies
Lipid profile	Pilot studies in postmenopausal women	7 g/day for 3 months	Small improvement in cholesterol and antioxidant status
Anaemia and nutrition	Community feeding studies	Leaf powder in food	Improved nutrient intake, variable effect on haemoglobin
Asthma	Small study in mild to moderate asthma	Seed kernel powder	Improved lung function in a few patients

Most of these studies have weaknesses such as small sample size, short duration, no standardization of the preparation and lack of blinding. A review by Stohs and Hartman (2015) pointed out the same limitations. Larger and better controlled trials, using standardized extracts with a known amount of marker compounds, are really needed before specific therapeutic claims can be made.

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Formulations and Commercial Products

Moringa is available in the market in many forms. Leaf powder, capsules and tablets, tea bags, extract powders, seed oil and cosmetic creams are the most common. In India, the plant is used in several polyherbal Ayurvedic preparations, and drumstick leaf powder is promoted under government nutrition schemes. Other applications include:

- **Nutraceuticals and functional foods:** fortification of bread, biscuits, noodles and yoghurt with leaf powder to raise protein, iron and antioxidant content.
- **Cosmetics:** ben oil is used in creams, hair oils and soaps because it is stable and has good emollient property.
- **Water treatment:** seed powder as a natural, biodegradable coagulant for turbid water. **Animal feed:** leaves are used as a protein-rich fodder supplement for cattle, poultry and fish.
- **Novel drug delivery research:** nanoparticles of silver and gold prepared using Moringa leaf extract as a reducing agent (green synthesis), and the use of seed gum as a pharmaceutical excipient (binder and suspending agent) are also being studied.

A problem with the supplement market is the lack of quality control. Products differ widely in the part used, the extraction method and the actual content of active compounds, and adulteration with other leaf powders is possible. Pharmacopoeial standards, authentication through macroscopic, microscopic and HPTLC fingerprinting, and testing for heavy metals, pesticide residues and microbial load are all required to make sure that a product is genuine and safe.

Discussion

The literature discussed above shows a plant with truly wide-ranging potential, and it is easy to understand why Moringa has been called a miracle tree. Yet one has to be honest about the level of proof. Almost every pharmacological claim rests on laboratory or animal data. Many of these studies use extremely high doses, crude extracts that are not chemically characterized, and sometimes weak methodology, for example no positive control or too few animals per group. Results for the same activity also differ between studies, which can be explained by variation in the plant material, season, region, drying and extraction methods.

Another point is that active compounds may not reach the body in the form studied in the laboratory. Isothiocyanates are reactive and unstable, and their release depends on myrosinase activity, which is lost in cooked or dried leaves. The bioavailability of quercetin glycosides and chlorogenic acid is limited as well. So the leap from "extract works in a cell" to "eating this will cure the disease" is a long one.

On the positive side, the plant has a very good safety record as food, a large number of different bioactive compounds, a low cost and wide availability. Its greatest proven value probably lies in nutrition, particularly in areas where protein, vitamin A and iron deficiencies are common, while its role as medicine is promising but not yet confirmed.

Limitations of the Existing Research

Lack of standardized extracts and defined marker compounds.

Few randomized, double-blind, placebo-controlled human trials.

Limited long-term toxicity and reproductive toxicity data.

Poor understanding of pharmacokinetics and herb-drug interactions. Publication of mostly positive results, with possible bias.

Future Prospects

Several directions look worthwhile. First, bioassay-guided fractionation could be used to isolate and fully characterize the compounds that are truly responsible for each activity, and moringin is an obvious candidate for drug development. Second, standardized extracts need to be prepared, with quantified markers, so that results from different laboratories can be compared. Third, well-designed clinical trials with adequate sample size should be done, especially for diabetes, dyslipidaemia, lactation and anaemia. Fourth, pharmacokinetic studies and interaction studies with commonly prescribed drugs should be carried out. Fifth, modern delivery systems, such as nanoformulations and

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microencapsulation, may be useful to protect unstable isothiocyanates and improve their absorption. Finally, sustainable cultivation and good agricultural and collection practices would give a consistent supply of good quality raw material.

II. CONCLUSION

Moringa oleifera is a nutritionally rich and pharmacologically versatile plant with a long history of use in traditional medicine. Its leaves, pods, seeds and other parts contain glucosinolates, isothiocyanates, flavonoids, phenolic acids and other compounds which, in laboratory and animal studies, show antidiabetic, antioxidant, anti-inflammatory, antimicrobial, anticancer, hepatoprotective, cardioprotective and neuroprotective effects. The safety profile of leaves at normal dietary levels seems favourable, although the root and bark should be avoided and caution is needed with high-dose supplements and during pregnancy.

At the same time, human evidence is limited, and the claims made in popular media are often ahead of the science. For a pharmacy student, the lesson is that Moringa is a promising nutraceutical and a good lead for further research, not a proven cure for any disease. With standardized preparations, rigorous clinical trials and proper safety evaluation, it could find a well-defined place in modern healthcare.

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