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# A Review of the Pharmacognostic and Pharmacological Characteristics of *Moringa oleifera leaves*

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**Abstract:**

*Moringa oleifera* is a valued medicinal plant in traditional folk medicine. Many pharmacological studies have shown the ability of this plant to exhibit analgesic, anti-inflammatory, antipyretic, anticancer, antioxidant, nootropic, hepatoprotective, gastroprotective, anti-ulcer, cardiovascular, anti-obesity, antiepileptic, antiasthmatic, antidiabetic, anti-urolithiatic, diuretic, local anesthetic, anti-allergic, anthelmintic, wound healing, antimicrobial, immunomodulatory, and antidiarrheal properties. This review is a comprehensive summary of the phytochemical and pharmacological activities as well as the traditional and therapeutic uses of this plant. *M. oleifera* has wide traditional and pharmacological uses in various pathophysiological conditions. We will review the various properties of *M. oleifera* (drumstick tree) and focus on its various medicinal properties. We think that it is an attractive subject for further experimental and clinical investigations.

**KEYWORDS:** *Moringa oleifera*, *pharmacological actions*, *phytochemistry*

## INTRODUCTION

Moringa oleifera (MO), also known as drumstick tree, is indigenous to South Asia, mainly in foothills of Himalayas, India, and it has been grown and naturalized in other countries such as Afghanistan, Nepal, Bangladesh, Sri Lanka, South and Central America, West Indies, Philippines, and Cambodia.[1,2] It is short, easy to cultivate, grows quickly, and does not shed its leaves in dry season, and its leaves are highly nutritious and rich in amino acids, vitamins, minerals, and natural antioxidants.[3,4,5,6,7] This was mentioned 5000 years ago in Charaka Samhita, and is well known in African folk medicine.[8] This review focuses on the phytochemistry and pharmacological activities of this plant.

PHYTOCHEMISTRY

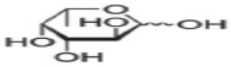
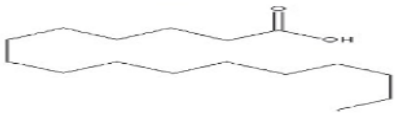
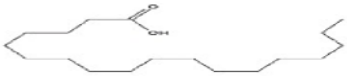
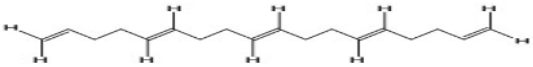
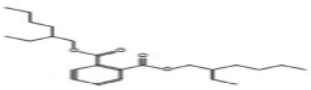
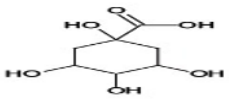
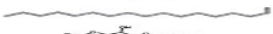
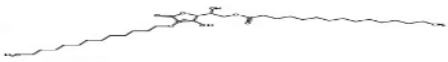
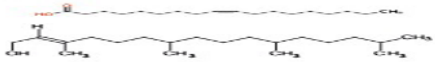
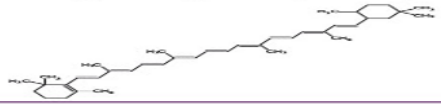
A pictorial depiction of MO is shown in Figure 1, and worldwide distribution of MO is shown in Figure 2. It is a storehouse of ingredients, among which major ones are carotenoids,[ tocopherols (α, γ, δ), flavonoids, phenolic acids, folate, polyunsaturated fatty acids, and various minerals. A list of some important phytoconstituents and their structures is given in Table 2. Gas chromatography–mass spectrometry study of the plant's leaf revealed a total of 35 compounds; important

compounds isolated were n-hexadecanoic acid, tetradecanoic acid, *cis*-vaccenic acid, octadecanoic acid, palmitoyl chloride, beta-l-rhamnofuranoside, 5-*O*-acetyl-thio-octyl, gamma-sitosterol, and pregna-7- diene-3-ol-20-one. E-lutein was found to be the most abundant carotenoid found in leafage. The plant's radicle contains 4-(α-l-rhamnopyranosyloxy)-benzylglucosinolate and benzylglucosinolate. Spirochin and anthonine found in roots show bactericidal activity. Beta-sitosterone, vanillin, 4-hydroxymellein, β-sitosterol, and octacosanoic acid are found in the peduncle of the plant, and its crust is composed of 4-(α-l-rhamnopyranosyloxy)-benzylglucosinolate.

Figure 1: "Miracle tree" *Moringa oleifera*

**Figure 2: Topographical distribution of *Moringa oleifera*.**


**Table 2: Structure of some important constituents of moringa oleifera**

| Serial no. | Name of compounds | Chemical structure |
|---|---|---|
| 1 | 1,2,3-Cyclopentanetriol |  |
| 2 | L-galactose, 6-deoxy |  |
| 3 | *n*-Hexadecanoic acid |  |
| 4 | Tetradecanoic acid |  |
| 5 | *cis*-Vaccenic acid |  |
| 6 | Octadecanoic acid |  |
| 7 | beta-l-Rhamnofuranoside,5-*O*-acetyl-thio-octyl- |  |
| 8 | Vitamin E |  |
| 9 | gamma-Sitosterol |  |
| 10 | Pregn-5,7-diene-3-ol-20-one |  |
| 11 | Squalene |  |
| 12 | 2,6-Dihydroxybenzoic acid |  |
| 13 | Bis(2-ethylhexyl) phthalate |  |
| 14 | Ethyl oleate |  |
| 15 | Quinic acid |  |
| 16 | Hexadecanal |  |
| 17 | L-(+) Ascorbic acid-2,6-dihexadecanoate |  |
| 18 | Oleic acid |  |
| 19 | Phytol |  |
| 20 | Beta-carotene |  |

Its stem contains alkaloids (moringine and moringinine), 4-hydroxymellein, octacosanoic acid, and β-sitosterol. Whole gum exudate contains l-rhamnose, d-glucuronic acid, l-arabinose, d-mannose, d-xylose, and d-galactose. Another important constituent present in gum is leucodelphinidin-3-O-B-D-galactopuranosy (1->4)-O-B-D-glucopyranoside.

Flowers contain sucrose, amino acids, alkaloids, and flavonoids, such as rhamnetin, isoquercitrin, and kaempferitrin. Taxonomic classification of Moringa oleifera is shown in Table 1.

| | |
|---|---|
| Kingdom | Plantae |
| Subkingdom | Tracheobionta |
| Super division | Spermatophyta |
| Division | Magnoliophyta |
| Class | Magnoliopsida |
| Subclass | Dilleniidae |
| Order | Capparales |
| Family | Moringaceae |
| Genus | *Moringa* |
| Species | *Oleifera* |

Source: Nadkarni KM. Indian materia medica. Vol. 1. 3rd ed. Bombay, India: Popular Prakashan; 2000. p. 811.[26]

Whole pods contain isothiocyanate, thiocarbamates, nitrile, *O*-[2′-hydroxy-3′-(2″-heptenyloxy)]-propyl undecanoate, methyl-*p*-hydroxybenzoate, and *O*-ethyl-4-[(α-l-rhamnosyloxy)-benzyl] carbamate. Fruits contain cytokines, whereas seeds contain high concentrations of benzylglucosinolate, 4-(α-l-rhamnopyranosyloxy)-benzylglucosinolate, 4-(α-l-rhamnosyloxy) benzylisothiocyanate, 4-(α-l-rhamnosyloxy) phenylacetonitrile, and *O*-ethyl-4-(α-l-rhamnosyloxy) benzyl carbamate.

## PHARMACOLOGICAL ACTIONS

### Analgesic, anti-inflammatory, and antipyretic activities

Almost every part of this “miracle tree” has been found to exhibit analgesic activity in different animal models. Extract of leaves, seeds, and bark showed significant analgesic activity in both central (hot plate method) and peripheral models (acetic acid–induced writhing method) in a dose-dependent manner,[ and extracts of leaves exhibited analgesic potency similar to that of indomethacin and antimigraine properties in a dose-dependent manner. Topical application showed efficacy against multiple sclerosis–induced neuropathic pain.

Anti-inflammatory activity of leaf extract has been observed in a carrageenan-induced paw edema model. Extracts of bark showed anti-inflammatory activity comparable to diclofenac in the same model. Anti-inflammatory properties of root have also been reported. Mechanism underlying the anti-inflammatory activity may be attributed to the regulation of neutrophils and c-Jun N-terminal kinase pathway. Active ingredients contributing to anti-inflammatory property are tannins, phenols, alkaloids, flavonoids, carotenoids, β-sitosterol, vanillin, hydroxymellein, moringine, moringinine, β-sitostenone, and 9-octadecenoic acid.

Leaf extract showed significant antipyretic activity in a Brewer’s yeast–induced pyrexia model. Ethanol and ethyl acetate extracts of seeds also showed significant antipyretic activity.

### Neuropharmacological activity

Aqueous extract of leaves has shown protection against Alzheimer’s disease in a colchicine-induced Alzheimer’s model using behavioral testing (radial Y arm maze task). It protected against Alzheimer’s disease by

altering brain monoamine levels and electrical activity. Another study using toluene-ethyl acetate fraction of methanolic extract of leaf showed potent nootropic activity. Leaf extract contains vitamins C and E, which play a significant role in improving memory in patients with Alzheimer's disease.

Anticonvulsant activity of leaves was shown in both pentylenetetrazole and maximum electric shock models using male albino mice. Aqueous extract of root suppressed penicillin-induced epileptic seizures in adult albino rats.

Ethanolic extract of leaves exhibited both central nervous system depressant and muscle relaxant activities in actophotometer and rotarod apparatuses, respectively, and also exhibited significant anxiolytic activity in staircase test and elevated plus maze test in a dose-dependent manner.

Anticancer activity

Alcoholic and hydromethanolic extracts of leaves and fruits showed a significant growth delay in tumor kinetics in mouse melanoma tumor model studies. Extract of leaf also exhibited antiproliferative activity on A549 lung cells. Exploration of effects on prerequisites for cancer metastasis showed that the administration of leaf extract into chick chorioallantoic membrane led to an antiangiogenic effect, which was dose dependent, thereby showing their remarkable anticancer potential. Another study reported that pod extract suppressed azoxymethane and dextran sodium sulfate–induced colon destruction in male, Institute of Cancer Research (ICR) mice. An extract of root and leaf showed a cytotoxic effect against breast cancer, hepatocarcinoma, and colorectal cancer cells *in vitro* and cisplatin-resistant ovarian cancer cells. Flower extract stimulated cell proliferation in normal cells but not in cancer cells, whereas leaf extract showed marked antitumor and hepatoprotective effects, these findings suggest the regenerative potential of MO besides its anticancer effects.

Phytoconstituents such as niazimicin, carbamates, thiocarbamate, nitrile glycosides and others such as quercetin and kaempferol are responsible for the anticancer activity of this plant.

Antioxidant activity

MO fruits and leaves have antioxidant properties. Extract of leaf showed a concentration-dependent increase in glutathione level and a decrease in malondialdehyde level, fruit extract showed beneficial results in eliminating free radicals, extract of roots significantly reduced iron and $FeSO_4$-induced microsomal lipid peroxidation in a dose-dependent manner. Pods were capable of scavenging peroxyl, superoxyl, and 2, 2-diphenyl-2-picryl hydrazyl (DPPH) radicals.

Besides displaying antioxidant activity, MO leaf extract also showed a dose-dependent nephroprotective action in an acetaminophen-induced nephrotoxicity model in male BALB/c rats. Triterpenoids, moringyne, monopalmitic and di-oleic triglyceride, campesterol, stigmasterol, β-sitosterol, avenasterol, vitamin A, and its precursor beta-carotene have been shown to contribute for antioxidant properties.

Effects on the reproductive system

Leaf extract showed a significant increase in the weight of testis, seminal vesicle, epididymis, and a higher score for epididymal maturity and lumen formation along with an increase in seminiferous tubule diameter (all doses).

Ethanolic extract of leaf protected prepubertal spermatogonial cells in Swiss male albino mice in cyclophosphamide-induced damage model; the possible underlying mechanism may be upregulation

of expression of c-Kit and Oct4 transcripts independent of p53-mediated pathway.

The abortive effect of leaf extract on rats after treatment for 10 days after insemination has been reported. Extract showed a synergistic effect with estradiol and an inhibitory effect with progesterone. Fresh leaves of MO contain approximately 11,300–23,000 IU of vitamin A, which has a major role in various anatomical processes, such as reproduction, embryonic growth and development, immunity development, and cell differentiation.

Hepatoprotective activity

Extract of leaves has shown hepatoprotective effects against carbon tetrachloride and acetaminophen-induced liver toxicity in Sprague Dawley rats. and also hepatoprotective effect against antitubercular drugs and alloxan-induced liver damage in diabetic rats. This plant-based diet for 21 days showed significant potential in attenuating hepatic injury. Alkaloids, quercetin, kaempferol, flavonoids, ascorbic acid, and benzylglucosinolate were found to be responsible for hepatoprotective activity.

Gastroprotective and anti-ulcer activities

Extract of leaves remarkably reduced ulcer index in ibuprofen-induced gastric ulcer model and in pyloric ligation test, and a significant reduction in cysteamine-induced duodenal ulcers and stress ulcers was also observed. Bisphenols and flavonoids could be contributing to this property.

Cardiovascular activity

Extract of MO leaf significantly reduced cholesterol levels and displayed a protective role on hyperlipidemia induced by iron deficiency in male Wistar rats. Antihypertensive effect of leaf extract on spontaneous hypertensive rats was shown, in addition to reduced chronotropic and inotropic effects in isolated frog hearts. Active constituents for hypotensive action are niazinin A, niazinin B, and niazimicin. Extract of leaves also showed cardioprotective effects against isoproterenol-induced myocardial infarction in male Wistar albino rats; the mechanism underlying this cardioprotective activity was found to be antioxidant effect, prevention of lipid peroxidation, and protection of histopathological and ultrastructural disturbances caused by isoproterenol.

A study was done of *Moringa oleifera* Lam. on various tissue systems and it showed reduction in inflammation and lipid accumulation.

Anti-obesity activity

Significant reduction in body mass index was observed after oral treatment with leaf powder compared with that in obese control. Treatment of hypercholesterolemia rats with methanolic extract of MO leaf for 49 days showed a remarkable reduction in total cholesterol, triglycerides, and body weight, moreover, liver biomarkers, organ weight, and blood glucose levels were also decreased. Mechanisms include downregulation of mRNA expression of leptin and resistin and upregulation of adiponectin gene expression in obese rats.

Antiasthmatic activity

Extract of seeds showed protection against asthma as investigated in various models; the proposed mechanism for this effect was a direct bronchodilator effect combined with anti-inflammatory and antimicrobial actions and inhibition of immediate hypersensitive reaction. Ethanol extract of seeds tested against ovalbumin-induced airway inflammation in guinea pigs showed a significant increase in respiratory parameters and reduction in interleukins in bronchoalveolar lavage.

Hematological activity

A randomized, double-blind, placebo-controlled study was carried out on women who were anemic with hemoglobin levels between 8 and 12g/dL and were treated with aqueous extract of moringa leaf, the results showed an increase in mean hemoglobin and mean corpuscular hemoglobin concentration. Another study revealed that when moringa was given to healthy human volunteers for 14 days, a significant improvement in platelet count was observed.

Antidiabetic activity

Extract of leaf showed significant antihyperglycemic and hypoglycemic activity in normal and alloxan-induced diabetic rats. An elaborate study was performed to determine the effect of aqueous leaf extract on lipid profile, body weight, glucose, plasma insulin, homeostatic model assessment, and oral glucose tolerance test in insulin-resistant (IR) and type 1 diabetic rat models. IR rats were fed a high-fructose diet, and type 1 diabetic rats were treated with Streptozotocin (STZ) (55 mg/kg). IR rats showed an increase in hyperinsulinemia, hyperglycemia, and body weight, whereas STZ-induced diabetic rats showed hyperinsulinemia and hyperglycemia. Leaf extract administration for 60 days returned all the abnormal parameters to normal levels.

Furthermore, extract of leaf inhibited the formation of advanced glycation end products by reducing monosaccharide-induced protein glycation. Glucomoringin, phenols, flavonoids, quercetin-3-glucoside, fiber, and phenol have been reported to be responsible for antidiabetic activity.

Anti-urolithiatic activity

Aqueous and alcoholic extracts of this plant showed anti-urolithiatic activity in a hyperoxaluria-induced rat model and in ethylene glycol–induced urolithiasis model.

Diuretic activity

Leaves, flowers, seeds, roots, and bark extracts increased urine output in rats, extract of leaf showed a dose-dependent diuretic action greater than control but less than hydrochlorothiazide. Campesterol, stigmasterol, β-sitosterol, and avenasterol were responsible for this activity.

Anti-allergic activity

Ethanolic extract of seeds inhibited passive cutaneous anaphylaxis induced by anti-immunoglobulin G (IgG) antibody and histamine release from mast cells; the mechanism underlying this action could be membrane-stabilizing actionand also reduced scratching frequency in an Ovalbumin sensitization model.

Anthelmintic activity

This plant showed potent anthelmintic activity, it took less time to paralyze Indian earthworm *Pheretima posthuma*. In ovicidal assay, ethanolic and aqueous extracts showed 95.89% and 81.72% egg hatch inhibition, respectively, and in larvicidal assay, they showed 56.94% and 92.50% efficacy, respectively.

Wound-healing activity

Extracts of leaf, dried pulp, and seeds showed a significant increase in hydroxyproline content, wound-closure rate, granuloma-breaking strength, and granuloma dry weight, and a decrease in scar area and skin-breaking strength in incision, excision, and dead space wound models in rats.[

Studies conducted on the effect of wound healing of leaf extract in diabetic animals showed improved tissue regeneration, decreased wound size, downregulated inflammatory mediators, and upregulated vascular endothelial growth factor in wound tissues, and remarkable antiproliferative and anti-migratory effects on normal human dermal fibroblasts.

Antimicrobial activity

Ethanolic extract of leaf showed antimicrobial activity against all the tested bacteria. Chloroform extract reported activity against pathogens such as *Salmonella typhi, Pseudomonas aeruginosa, Escherichia coli*, and *Vibrio cholerae*.

Ethanolic extracts of root and bark possessed antifungal activity against *Aspergillus niger, Neurospora crassa, Rhizopus stolonifer*, and *Microsporum gypseum*, and also showed inhibitory activity against *Leishmania donovani*. Many studies suggest that extracts of seeds could be a potential option to purify water sources as it inhibited bacterial growth in agar and nutrient medium.

Methanolic extract of leaves inhibited urinary tract pathogens, such as *Staphylococcus aureus, Klebsiella pneumoniae, S. saprophyticus*, and *E. coli*.

Flavonoids, tannins, steroids, alkaloids, saponins, benzyl isothiocyanate, and benzylglucosinolate were found to be responsible for antimicrobial activity, whereas pterygospermin was found to be responsible for antifungal activity.

Immunomodulatory activity

Methanolic extract of this plant stimulated both humoral and cellular immune response. In addition, extract showed an increase in optical density and stimulation index, indicating splenocyte proliferation.

Antidiarrheal activity

Extract of seeds showed significant reduction in gastrointestinal motility and were found to be effective in castor oil induced diarrhoea in male Wister rats. Antidiarrheal activity can be attributed to phytochemical ingredients such as tannins, saponins, and flavonoids.

Miscellaneous effects

Leaf extract exhibited a reduction in unwanted sebum secretions from sebaceous gland during winter in humans. A systematic review and meta-analysis have clearly accounted this plant as a galactagogue. Methanolic extract of root showed local anesthetic action in frog and guinea pig models. Significant CYP3A4 inhibitory effects was exhibited by MO leaf extract. Thus, MO has a great potential for herb–drug interactions.

## Conclusion

The key objective of this review was to unfold and explore the pharmacological and medicinal values of MO; preclinical studies revealed that this plant possesses analgesic, anti-inflammatory, antipyretic, anticancer, antioxidant, nootropic, hepatoprotective, gastroprotective, anti-ulcer, cardiovascular, anti-obesity, antiepileptic, antiasthmatic, antidiabetic, anti-urolithiatic, diuretic, local anesthetic, anti-allergic, anthelmintic, wound healing, antimicrobial, immunomodulatory, and antidiarrheal effects. These activities may be attributed to phytoconstituents present in its root, stem, bark, leaf, flower, pod, and seeds. MO offers immense value, which can form the basis of drug supplementation, and should be used for the promotion of public health. It may also be considered for the treatment of different diseases as an alternative therapy.

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