ISSN Print: 2664-6536
ISSN Online: 2664-6544
Impact Factor: RJIF: 5.51
IJBB 2025; 7(2): 142-148
www.biosciencejournal.net
Received: 06-05-2025
Accepted: 08-06-2025

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Medicinal and traditional use of the miracle tree drumstick (*Moringa oleifera*): A review

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DOI: https://www.doi.org/10.33545/26646536.2025.v7.i2b.160

Abstract
The leaves and pods of Moringa (Drumstick) are commonly eaten in India. All parts of this plant including root, bark, gum, leaf, fruit (pods), flowers, seed, and seed oil of the Moringa have been used as ingredients in traditional herbal medicines. It has been established as a rich source of phenolics and glucosinolates, minerals, tocopherols, carotenoids, polyunsaturated fatty acids, ascorbic acid, and folate. The presence of phytochemicals and other necessary elements in this plant, makes it valuable for life of human and animal beings. The present paper is review of medicinal and traditional use of *Moringa oleifera* (Drumstick).

Keywords: *Moringa oleifera*, medicinal uses, traditional medicine, phytochemicals, nutritional value, antioxidant properties, herbal remedies, health benefits

1. Introduction
Moringa (Drumstick) plant is used in the functional and traditional foods and also has beneficial influence on digestion and has the ability to preserve foods. It is the most widely cultivated species of the genus *Moringa*, which is the only genus in the family Moringaceae. It is a fast-growing, deciduous tree that can attain a height of approximate 10 to 15feet. The bark has a whitish-grey colour and is surrounded by thick cork. Young shoots have purplish or greenish-white, hairy bark. This tree has an open crown of drooping, fragile branches with a feathery foliage of tripinnate leaves. The fruit is a hanging, three-sided brown capsule of varying sizes about 20 to 45 cm which holds dark brown, globular seeds. The seeds have three whitish papery wings. The leaves, flowers, pods and seeds, are the foremost parts of this tree (Image I, II, III & IV).
It has been used in the traditional medicine passed down for centuries in many cultures around the word, for skin infections, anemia, anxiety, asthma, blackheads, blood impurities, bronchitis, catarrh, chest congestion, cholera, conjunctivitis, cough, diarrhea, eye and ear infections, fever, glandular, swelling, headaches, abnormal blood pressure, hysteria, pain in joints, pimples, psoriasis, respiratory disorders, scurvy, semen deficiency, sore throat, sprain, tuberculosis, for intestinal worms, lactation,diabetes and pregnancy The healing properties of Moringa oil, have been documented by ancient cultures. Moringa oil has tremendous cosmetic value and is used in body and hair care as a moisturizer and skin conditioner (Ramachandran *et al*., 1980) [64].
Leaves, seeds, roots, flowers and pods of Moringa are suitable for human and animal consumption (Leone *et al.*, 2016) [44]. From ancient times, it has been a regular component of conventional eatables in India. It is a multipurpose herbal plant and an alternative for medicinal purposes worldwide (Abdull Razis *et al.*, 2014) [1]. It is used as potential antioxidant, anticancer, anti-inflammatory,antiulcer, antihyperglycemic, antidiabetic and antimicrobial agent (Bhishagratna, 1991; Bennett *et al.*, 2003; Babu and Chaudhuri, 2005; Verma *et al.*, 2009; Hamza, 2010; Arora *et al.*, 2013; Abdull Razis *et al.*, 2014) [19, 18, 17, 78, 35, 13, 1].

Leaves of *Moringa*
The leaves are a promising source of K, Mg, Ca, P, Zn, Fe, Cu, Mn and vitamins A, E and C (Leone *et al.*, 2015a; Leone *et al.*, 2015b; Arumugam *et al.*, 2017) [42, 43, 15]. Its leaves can be eaten afresh, cooked or stored as dried powder for many months without refrigeration, which do not lose its nutritional value (Hsu *et al.*, 2006; Singh, 2010) [36, 68].

Availability of various types of antioxidant compounds in the leaves make a valuable source of natural antioxidants (Anwar *et al.*, 2007) [10] and a good source of nutraceuticals, besides as a functional component (Makkar and Becker, 1996) [47]. The biological value of leaves is immense and the boiled leaves exhibited three times more bio-available iron than the raw leaves. Similar results were observed in the powdered *Moringa* leaves (Arumugam *et al.*, 2017) [15]. *Moringa* leaves have been reported to be a rich source of carotene, protein, vitamin C, calcium and potassium and act as a good source of natural antioxidants; and thus enhance the shelf-life of fat containing foods (Dillard and German, 2000; Siddhuraju and Becker, 2003) [24, 67]. On comparison with standard sources of nutrition, the leaves contained 7 times the vitamin C of oranges; 4 times the vitamin A of carrots; 4 times the Ca of milk; 3 times the K of banana; and 2 times the protein of yogurt. Moreover, the micro-nutrient content is even higher in dried leaves, *i.e.*, 10 times the vitamin A of carrots; 17 times the Ca of milk; 15 times the K of bananas; 25 times the Fe of spinach; and 9 times the protein of yogurt. However, vitamin C dropped to half that of oranges (Mahatab *et al.*, 1987; Manzoor *et al.*, 2007) [46, 48]. The leaves are highly nutritious and recommended for infants and nursing mothers especially those from developing countries. *Moringa* helps in increasing womens' milk during breast feeding months (Estrella *et al.*, 2000; Siddhuraju and Becker, 2003; Anwar *et al.*, 2007) [28, 67, 10]. Alternatively, leaves may also be used as animal fodder (Ponnuswami, 2012) [62].

Flower and Pods

The flowers are pleasantly fragrant, yellowish-white in colour. Fresh or dried flowers are used for making teas (Ponnuswami, 2012) [62] with hypecholesterolemic properties (Gopalakrishnan *et al.*, 2016) [33] and also contains Ca, Kandamino acids. The flowers are said to taste like mushroom when fried (Arise *et al.*, 2014) [12]. The flowers act as hypecholesterolemic, and theanti-arthritic agents can cure urinary problems and cold (Sutalangka *et al.*, 2013) [72]. Flowers contain 9 amino acids, sucrose, D-glucose, traces of alkaloids, wax, quercetin and kaempferat (Image-III & IV).

The fruit is a pendulous, linear, three-sided capsule (referred as a pod, is initially green and tender), and it ripens in about three months after flowering. The pods become brown and dry at maturity and split open into 3 parts longitudinally. Each pod usually contains 12 to 35 seeds. Pods are believed to be anthelminitic, and are used for infections of the liver and spleen and also in treating articular pains (pain in the joints).

Seeds have a high content of methionine and cysteine, close to that reported for milk and eggs (Oliveira *et al.*, 1999) [57]. Therefore, they can be consumed together with legumes which are deficient in sulphur amino acids. Moreover, seeds seem to be free of trypsin inhibitor and urease activity, confirming the high protein digestibility (93%) of *Moringa* seeds (Oliveira *et al.*, 1999; Santos *et al.*, 2005) [57, 66].

The seeds have attracted scientific interest as *Moringa* seed kernels contain a significant amount of oil (up to 40%) with a high-quality fatty acid composition (oleic acid >70%) and, after refining, possess a notable resistance to oxidative degradation (Anwar *et al.*, 2005) [11]. The oil, commercially known as "*Ben oil*" or "*Behen oil*", is aliquid at room temperature and golden yellow in color. Its properties make it suitable for both human consumption and commercial purposes. In fact, *Moringa* oil could be a good substitute for olive oil in the diet as well as for non-food applications, like biodiesel, cosmetics and a lubricant for fine machinery. Moreover, after oil extraction, the seedcake can be used in waste water treatment as a natural coagulant (Ndabigengesere and Subba Narasiah, 1998) [53] or as an organic fertilizer to improve agricultural productivity (Emmanuel *et al.*, 2011) [27]. *Moringa* oil was also used as skin ointments ever since the Egyptian times (Abdull Razis *et al.*, 2014) [1].

Nourishing properties

Almost all parts of the *Moringa* can be eaten or used as ingredients in traditional herbal medicines. The leaves and pods are commonly eaten in parts of India and Africa (Stohs and Hartman, 2015) [70]. The leaves are an excellent source of many vitamins and minerals. 21 g chopped leaves contains 2 g protein, besides, vitamin B_6 (19%), vitamin C (12%), Iron: (11%), Igvwilo *et al.* (2017) [37] reported nutrients composition of leaf, seed and root (Table 1).

Several antioxidant plant compounds have been found in the leaves of *Moringa* (Chumark *et al.*, 2008; Arti *et al.*, 2009) [22, 14]. In addition to vitamin C and beta-carotene, these include (Amaglo *et al.*, 2010; Coppin *et al.*, 2013) [8, 23] Quercetin, which is a powerful antioxidant that may help lower blood pressure (Edwards *et al.*, 2007; Symonsand Jalili, 2012) [25, 73] too. One study in women found that consuming 7 g of *Moringa* leaves powder every day for three months significantly increased the blood antioxidant levels (Kushwaha *et al.*, 2014) [41]. *Moringa* leaves extract may also be used as a food preservative, as it increases the shelf life of meat by reducing oxidation (Ahmad *et al.*, 2015) [4].

Used by Human and Animals

Animals like cattle, goat and sheep, rabbits as well as pigs easily eat green leaves and stems of *Moringa*. (Mulugeta and Fekadu, 2014) [51] which increases the cattle's weight gain up to 60% (Aknbamijo *et al.*, 2004) [7], body weight gain, feed and protein intake of Murrah buffalo calves (Aharwal *et al.*, 2018). *Moringa* supplementation resulted in the highest average body weight gain in Bengal goats, besides the nutrient intake and improved digestibility were also observed by animals when *Moringa* leaves were used as a fodder. *Moringa* diet has the highest efficiency of protein utilization, nutrient digestibility and nitrogen utilization (Sultana *et al.*, 2015) [71].

The key uses of Moringa include human nutrition (leaves, seeds, flowers), alley cropping (biomass production for biodiesel and fertilising), animal forage (leaves and treated seepod-cake), biogas (from leaves), domestic cleaning agent (crushed leaves), blue dye (wood), fencing (living trees), fertiliser (seed-cake), foliar nutrient (juice expressed from the leaves), green manure (from leaves) (Fuglie, 1999; Popoola and Obembe, 2013; Leone *et al.*, 2015) [31, 63, 43]. The species is also mainly used as gum (from tree trunks), honey and sugar cane juice-clarifier (powdered seeds), honey (flower nectar), medicine (all plant parts), ornamental plantings, biopesticide (soil incorporation of leaves to prevent seedling damping off), pulp (wood), rope (bark), tannin for tanning hides (bark and gum), water purification

(powdered seeds) (Fuglie, 1999; Adebayo *et al.*, 2011; Popoola and Obembe, 2013; Leone *et al.*, 2015) [31, 2, 63, 43].
Moringa oleifera is the cheapest and credible alternative to not only providing good nutrition, but also to cure and prevent a lot of diseases (Paliwal *et al.*, 2011) [61]. Actually, the great interest in *M. oleifera* is related to its multipurpose uses and its ability to guarantee a good yield, where other crops cannot, in countries where people are mostly at risk of suffering from nutritional deficiencies (Leone *et al.*, 2015) [43].
Moringa leaves extract (MLE) contains K, Ca, carotenoids, phenols and zeatin (Asaolou *et al.*, 2012) [16] which increases yield of onions, bell pepper, maize, soya, coffee, tea, chilli, melon etc., by 25-30% (Mulugeta and Fekadu, 2014) [51], However, foliar spray should be used in addition to other sound agronomic practices. Extract from *Moringa* leaves is a low cost, natural plant growth enhancer that increases plant's tolerance to adverse environmental conditions (El-Hack *et al.*, 2018) [26].

Application in medicine of *Moringa*
Chemical compounds isolated from *M. oleifera* have been shown to contain useful pharmacological properties with prospective medicinal applications. A list of possible medical applications conferred by *M. oleifera* plant parts includes, but is not limited to, antihypertensive, anticancer, antispasmodic, antitumor, antiulcer, cholesterol lowering, diuretic, hepatoprotective, and hypoglycemic capabilities, as well as treatment of infectious skin and mucosal diseases (Caceres *et al.*, 1991; Guevara *et al.*,1991; Anwar *et al.*, 2007) [21, 34, 10]. Leaf extracts have been used to treat hyperthyroidism and currently have application as an anti-Herpes Simplex Virus Type-1 medicine (Lipipun *et al.*, 2003; Tahiliani & Kar. 2004) [45, 74].

Presence of phytochemicals in seeds
The seeds contains 4(alpha-L-Rhamnosyloxy) benzyl isothiocyanate, 4(-L- rhamnosyloxy) phenylacetonitrile, 4-hydroxyphenylacetonitrile, and 4-hydroxyphenyl-acetamide, 4-(alpha-l-rhamnopyranosyloxy)-benzylglucosinolate Roridin E, Veridiflorol, 9-Octadecenoic acid, O-ethyl-4-(alpha-L- rhamnosyloxy) benzyl carbamate, niazimicin, niazirin, beta- sitosterol, glycerol-1-(9-octadecanoate), 3-O- (6'-O oleoyl- beta-D-glucopyranosyl)-beta-sitosterol and beta-sitosterol-3- O-beta-D-glucopyranoside (Amaglo *et al.*, 2010; Oluduroa *et al.*,2010; Yongabi, 2010; Mehta *et al.*, 2011). Many researchers were reported that several phytochemicals are present in seeds of *Moringa* (Table 2).
Moringa oleifera seeds have been reported to produce sludge that is more compact (Ghebremichael & Hultman, 2004; Tat *et al.*, 2010) [32, 75] hence reducing sludge volume. The sludge produced is very biodegradable and can be used as a bio-fertilizer to increase the yield of sample food (Ghebremichael & Hultman, 2004; Kumar *et al.*, 2012) [32, 40].

Antimicrobial compounds
Numerous antibacterial compounds have been isolated from *M. oleifera*, including: glucosinolates, rhamanose, pterygospermin, and isothiocyanates. Specifically, these compounds include benzyl isothiocyanate (Fahey *et al.*, 2003) [30], niazimicin (Osrin *et al.*, 2004) [59], pterygospermin (Anwar *et al.*, 2007) [10], and 4-benzyl glucosinolate (Fahey, 2005) [29].
Out of these chemical constituent, An active antimicrobial agent ascribed to plant synthesized derivatives of benzyl isothiocyanates known as 4 *(α-L- rhamnosyloxy) benzyl isothiocyanate* was identified from earlier researches and about 8-10% of this compound is present in both defatted (after removing oil) seed and crude seed. This antimicrobial active agent has been reported to exert *in vitro* bactericidal activity against both gram positive and gram-negative bacteria in raw water.

Seed extract preparation
Traditionally, in Sudan, *Moringa oleifera* seed extracts are prepared by manually removing the dry seeds from their shells, grinding in mortal and pestle then soaking in water, and finally sieving the solution using a sieve of a particular mesh size or through a Mushin cloth (Jahn *et al.*, 1979) [38] the resulting extract is then used in treating water. This is considered as a low technology of *Moringa oleifera* seed processing because it is suitable for households and the sludge produced can be used as a bio-compost. Over the time, the removal of the seed oil either by organic solvent extraction (by using normal hexane), cold pressing, or steam extraction gained popularity after which the defatted (removal of oil) seed cake extract is used in purifying water. This type of seed processing is considered as medium technology because it is suitable for medium to large communities and there are other by-product such as the oil which can be processed as edible oil, the seed shells can be processed to become activated carbon, and the sludge produced can be used as bio-fertilizer. Ali *et al.*, (2010) [6], introduced an innovative method of processing the seed by further treating the defatted seed cake extract with microfiltration to enhance more isolation of bioactive compounds from the extract before using it to treat water.

Cultivation of *Moringa*
Moringa (Image 1& II) grows in almost all type of soils except stiffy clays, however, deep sandy loam soil with pH of 6.5 to 8 is most suitable for cultivating this crop. *Moringa*'s economic cropping period is three years and it can be propagated by seeds (annual *Moringa*), limb cuttings (perennial *Moringa*) during July to October. The crop is highly cross pollinated due to heteromorphic and entomophilous nature, honey bees (*Aphis mellifera*) being the most common pollinators (Arumugam *et al.*, 2017) [42].
Moringa oleifera is propagated in two main ways; by sowing and by cutting. The preference for a propagation mode varies among countries. Traditionally, in Sudan seeds are preferred; while vegetative propagation is common in India, Indonesia and in some areas of West Africa (Palada, 1996; Leone *et al.*, 2015) [60, 43]. To lift the dormancy of the seeds, they are soaked in water for 12 hours of time. Seeds germinate within two weeks, at a maximum of 2 cm depth. When sowing is planned in nursery, the seedlings can be transplanted when they reach about 30 cm (3-6 weeks after germination) (Ojiako *et al.*, 2011) [56]. Under ideal storage conditions (3 °C, 5-8% moisture), the germination rate is approximately 80-90% (Leone *et al.* 2015) [43]. However, the viability decreases when seeds remain at ambient temperature and high relative humidity; their germination rate dropping to 7.5% after three months (Morton, 1991) [50].

According to Leone *et al.* (2015) [43] cutting is preferred when seed availability is scarce and/or when labour is not a limiting factor. Plants raised from seeds produce fruits of poorer quality (Ramachandran *et al.*, 1980) [84]. Animashaun (2013) [9] argues that trees grown from seeds develop longer roots (an advantage for stabilisation and access to water) compared to those grown from cuttings that have much shorter roots. Since the tree vigorously re- sprouts after cutting, pruning or pollarding are usually practiced to enhance lateral branching and give the tree a bush shape in order to facilitate the harvest (Leone *et al.*, 2015) [43]. *Moringa oleifera* seeds have been reported to produce sludge that is more compact (Ghebremichael & Hultman, 2004) [32] hence reducing sludge volume. The sludge produced is very biodegradable and can be used as a bio-fertilizer to increase the yield of sample food (Ghebremichael & Hultman, 2004; Kumar *et al.*, 2012) [32, 40]

Conclusion

Several bioactive compounds (phytochemicals) have been investigated from *Moringa* and *Moringa oleifera* plant has nutrional, antimicrobial and medicinal properties. Different plant parts of *Moringa* can be frequently used in treatment of plant, human and animal diseases.

Table 1: Nutrients composition of root, leaf and seed (Igwilo *et al.*, 2017) [37]

S. No.	Nutrient	Root	Leaf	Seed
1	Energy values (Kcal/100 g)	384.05	426.12	426.12
2	Crude proteins (%)	5.02	27.60	28.02
3	Crude lipids (%)	6.33	20.00	33.78
4	Carbohydrates (%)	76.75	33.93	28.77
5	Ash (%)	4.97	11.60	3.03
6	Thiamine B1 (mg/100 g)	-	18.47	-
7	Riboflavin B2 (mg/100 g)	-	14.82	-
8	Pyridoxine B6 (mg/100 g)	-	57.29	-
9	Ascorbic acid (mg/100 g)	48.13	773.30	94.74
10	Niacin B3 (mg/100 g)	-	50.35	-
11	Calcium (mg/100 g)	3.99	13.45	2.84
12	Sodium (mg/100 g)	514.80	104.06	129.03
13	Potassium (mg/100 g)	15.4	20.81	-

Table 2: Phytochemicals present in *Moringa oleifera* seed

Name of Phytochemicals	Extraction solvents			Scientists
	Water	Ethanol	Methanol	
Alkaloids	+	+	+	Aja *et al.*,2011; Sinha,2012
Tannins	+			Kawo *et al.*, 2009
Flavonoids		+	+	Bukar *et al.*,2010
Saponin		+		Ogbe & Affiku (2011)
Terpenoids			+	Sinha,2012
Glycosides			+	Ogunjinmi & Oladipo-abodunwa,2012
Steroidal rings			+	Sinha,2012
Cardiac glycosides			+	Sinha,2012
Crude proteins	+			Kawo *et al.*, 2009

Sign + means available

Image-1

Image-II

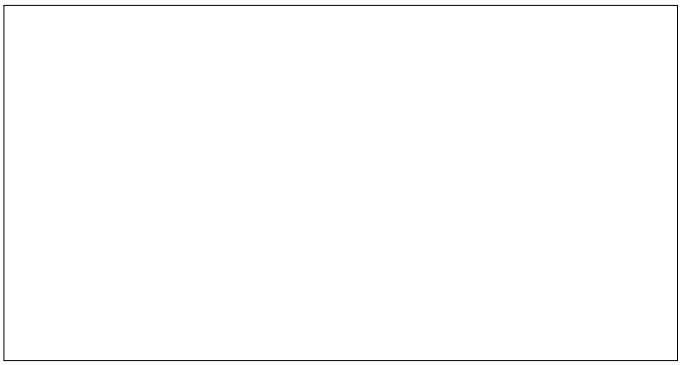

Image-III

Image-IV

Acknowledgement
The author is thankful to Prof. (Dr.) R.K. Pandey, Principal, Post Graduate College, Ghazipur, U.P., India for provide the library facility.

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