The incredible queen of green: Nutritive value and therapeutic potential of *Moringa oleifera* Lam.

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**ABSTRACT**

*Moringa oleifera*, rightly called as the miracle tree, is the extensively grown and highly valuable species of Moringaceae family. The tree has a pantropical distribution with nativity to Indian subcontinent. Nutritionally and therapeutically, it is a highly valued plant. Vitamins, proteins, β-carotene, aminoacids and various phenolics such as β-sitosterol, caffeoylquinic acid, kaempferol, quercetin and zeatin with potential for nutritional and therapeutic applications are enriched in different plant parts. Different plant parts of this plant such as roots, leaves, bark, flowers, fruit of immature pods and seeds possess a number of therapeutic properties such as diuretic, antipyretic, antioxidant, anti-inflammatory, antihypertensive, antitumor, antilulcer, antispasmodic, antidiabetic, cholesterol lowering, hepatoprotective and antimicrobial activities, and are being operational in various traditional medicine system for curing different health problems. *Moringa* is highly beneficial in depression, malnutrition, general weakness and osteoporosis. The present review is intended to emphasize the phytochemical constitution, traditional medicinal uses along pharmacological properties with the purpose to create public awareness regarding therapeutic and nutritive potential of this multipurpose tree as well as to facilitate the pharmacists and the researchers to fill the gap by exploring novel therapeutic compounds that will, of course, be in favor of humanity.

1. Introduction

*Moringa oleifera* Lam. (synonym: *Moringa pterygosperma* Gaertn.) (*M. oleifera*) known in 82 countries by 210 different names is well known by the name of the miracle tree. It is one of the extensively cultivated and highly valued members of Moringaceae, a monogeneric family, comprising of thirteen perennial angiosperm shrubs and trees[1-3]. *Moringa* tree is endemic to the Himalayan foothills of Pakistan, Afghanistan, Bangladesh and India, and is cultivated throughout tropics. It is recognized by a mixture of vernacular names, among of them, drumstick tree, horseradish tree, ben oil tree and malunggay are the most commonly reported in the history of this plant[4]. In Pakistan, Sohanjna is the vernacular name of *M. oleifera*[5,6]. It yields low quality timber, as it is a softwood tree, but it is believed for centuries that this plant possesses a number of industrial, traditional and medicinal benefits[7]. Fertilizer (seed cake), green manure (leaves), blue dye (wood), fencing (living trees), domestic cleaning agent (crushed leaves), alley cropping, animal feed (leaves and seed cake), medicine (all plant parts), foliar nutrient (juice expressed from the leaves), gum (tree trunks), biogas (leaves), biopesticide, ornamental plantings, water purifier (powdered seeds), honey (flower nectar) are different uses of this plant reported in literature[2,6,8-20].

*M. oleifera* is a good source of aminoacids and contains a number of important minerals, β-carotene, various phenolics and vitamins[21,22]. *M. oleifera* is also an important vegetable food article of trade, particularly in Pakistan, Hawaii, Philippines, Africa and India which has a huge deliberation as the natural nutrition[1,23]. In South Asia, various plant parts, including leaves, bark, root, gum, flowers, pods, seeds and seed oil are used for the variety of infectious and inflammatory disorders along with hepatorenal, gastrointestinal, hematological and cardiovascular diseases[22,24-26]. Various therapeutic potentials are also credited to different parts of
the highly incredible tree. The plant is reported to have antitumor, hepatoprotective, analgesic, antispasmodic, antipyretic, antilucre, diuretic, hypotensive, hypolipidemic and antimicrobial activities.

2. Morphological characters

*M. oleifera* is a perennial tree (maximum height: 7–12 m; diameter: 20–40 cm). The alternate, compound, pinnae and grayish-downy leaves (20–70 cm long) grow mostly at the tips of branches (Figure 1). Long petiole with 8–10 pairs of pinnae alternatively, each has two pairs of elliptic or obovate leaflets and one leaflet is present at apex which is 1–2 cm long; glands are present at the base of pinnae and petioles[10]. The flowers (2.5 cm wide), cream or white colored and yellow-dotted at the base are fragrant, produced in highly profuse form in axillary and arranged in drooping panicles (Figure 1)[10]. The fruits are hanging down from the branches represented by three lobed pods (20–60 cm long). When the pods become dry, they break into three parts. The round seeds (12–35 cm long) with a brownish semi-permeable seed hull are present in each pod (Figure 1)[27].

3. Phytochemistry

The leaves contain niazirinin and niazirin-nitrile glycosides, 4-[[4'-O-acetyl α-L-rhamnosyl (oxy)] benzyl isoiochyanate, and niaziminin B, niaziminin A-three mustard oil glycosides, athisiocarbamate, niaziminin, quercetin-3-O-glucoside, 4-(α-L-rhamnopyranosylxylo) benzylglucosinolate and quercetin-3-O-(6”-malonyl-glucoside), 3-caffeoyl quinic acid, kaempferol-3-O-glucoside and kaempferol-benzylglucosinolate and quercetin-3-O-(6”-malonyl-glucoside), niazirinin, quercetin-3-O-glucoside, 4-[(4'-3. Phytochemistry]

4. Traditional health benefits of *M. oleifera*

The traditional knowledge of *Moringa* is present in over 200 languages known in more than 80 countries, including Pakistan. *Moringa* plant has been used by Greek, Egyptian, Roman and Indian societies with writings dating back as far as 150 AD. This plant showed that ancient queens and kings used fruits as well as leaves of this miracle tree in their diet to maintain mental alertness[2]. Traditionally, *Moringa* is used as expectorant, stimulant, diuretic and antispasmodic. Root is used as vesicant and is acrid. Internally, it is used as stimulant, antilithic and diuretic (Table 1). Seeds are used as stimulant. Bark is used as antifungal, emmenagogue, antibacterial. Flowers are used as tonic, diuretic and stimulant. The plant is also antiseptic and a cardiac tonic[32]. Pods are used as anthelmintic, antipyretic and anti-diabetes. Root juice is employed as an antiepileptic, cardiac tonic, brain tonic, diuretic, anti-inflammatory, and also used for asthma, enlarged spleen and liver[33]. Decoction is used in sore throat as a gargle. Fruits and roots are used as antiparalytic. The juice of leaf is effective in hiccup and cooked leaves are used for curing catarrhal affections and influenza. The bark of root is used as analgesic, antiviral, anti-inflammatory[34]. Stem bark and flower are hypoglycemic. Seed-infusion is diuretic, anti-inflammatory and antispasmodic. Dried root bark is used in glycosuria, goitre and lipid disorders. Root, stem bark, leaf and seeds are used in piles[29] (Table 1).

**Figure 1.** *M. oleifera* morphology. a: Leaves; b: Flowers; c: Pods; d: Seeds.
Table 1
Traditional health benefits of *M. oleifera*.

<table>
<thead>
<tr>
<th>Plant parts</th>
<th>Health benefits</th>
<th>References</th>
</tr>
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<tbody>
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<td>Leaves</td>
<td>Leaves relieve headache by rubbing the temple</td>
<td>[6,7,29,35,36]</td>
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<tr>
<td></td>
<td>Poultice of leaves stop bleeding from cuts</td>
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<td>Leaf extracts were used for skin problems caused by bacteria and fungi</td>
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<td>The leaves are prescribed for anemia</td>
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<td>Dried leaves treat diarrhea</td>
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<td>Boiled <em>Moringa</em> flowers taken as a tea is effective for cold and influenza</td>
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<td>Roasted seeds treat rheumatism, arthritis, gout, cramp and boils. Pounded seeds mixed with coconut oil are applied to the problem area</td>
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<td>Bark is also used as appetizer</td>
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<tr>
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<tr>
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Figure 2. Chemical constituents from *M. oleifera*. 

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5. Nutritional facts and pharmacological properties of M. oleifera

*Moringa* is a tree that grows in almost ramshackle areas of the earth. It seems that God packed this tree with almost all the essential nutrient and made it to be pharmacy full of natural medicines in bio-available form to feed the poor of rural and barren areas. With more than 90 recognized nutrients, 36 anti-inflammatories, 46 antioxidants, *Moringa* is the most enzymatically active and nutrient-dense plant known to mankind[43]. It is analyzed scientifically that *Moringa* contains more than 539 bio-chemical activities that are absolutely beneficial to man[44]. A huge array of nutritional and medicinal qualities have been accredited to bark, roots, leaves, fruits, flowers and seeds.

5.1. Nutritional benefits

A bulk of reports exist in literature on the nutritional values of *Moringa*. The nutritional contents include vitamin A, which provides protection against skin diseases, eye disease, gastrointestinal ailments, heart ailments and many other health problems; vitamin C, which enhances immunity during different complaints including flu and colds; Ca, which makes the teeth and bones strong and prevents osteoporosis and K, which is essential for proper brain functioning and proteins, the building blocks of cells of our body[2,45]. *Moringa* leaves contained the variety of essential amino acids which are proteins sub-units. The leaves could be fortunate to those peoples who are poor and unable to get the protein component of their diet from meat. *Moringa* contains histidine and arginine. Aminoacids are important, especially for infants who unable to make enough protein for their growth requirements.

*Moringa* fresh leaves were compared with other food products placed the *Moringa* on the top. It contains four times the Ca of milk, four times the vitamin A of carrots and three times the K of bananas. But the dried leaves contain even more micro-nutrient content (17 times Ca of the milk, ten times vitamin A of the carrots, 15 times K of the bananas and 25 times the iron of spinach). However, vitamin C drops to about half that of oranges[45] (Table 2). The mineral contents of *M. oleifera* leaves are 0.11 mg/kg of Mg, 1.36 mg/kg of P, 2.73 mg/kg of Na, 21.7 mg/kg of K, 26.4 mg/kg of Ca, 175 mg/kg of Fe, 51.8 mg/kg of Mn, 13.7 mg/kg of Zn and 7.1 mg/kg of Cu. Keeping in view the nutritional facts, there is a great opportunity of its utilization in fortifying milk, juices, sauces, bread, spices and instant noodles. Many commercial products like tea, Zija soft drink and neutraceuticals are a few examples.

<table>
<thead>
<tr>
<th>Nutrient</th>
<th><em>Moringa</em></th>
<th>Other food</th>
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</thead>
<tbody>
<tr>
<td>Vitamin A</td>
<td>6.78 mg</td>
<td>Carrot: 1.89 mg</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>220.00 mg</td>
<td>Orange: 30.00 mg</td>
</tr>
<tr>
<td>Ca</td>
<td>440.00 mg</td>
<td>Cow milk: 120.00 mg</td>
</tr>
<tr>
<td>K</td>
<td>259.00 mg</td>
<td>Banana: 88.00 mg</td>
</tr>
<tr>
<td>Protein</td>
<td>6.60 g</td>
<td>Cow milk: 32.00 g</td>
</tr>
</tbody>
</table>

5.2. Health benefits

There is a saying: *Moringa* leaves can prevent 300 diseases. Now the recent research of modern science proved that the *Moringa* tree is packed with implausible constituents that can prevent many diseases.

5.2.1. Antimicrobial activity

Inhibitory effect of *Moringa* against various microbes in several laboratory bioassay has confirmed the presence of antimicrobial components. *Moringa* extract exhibited anti-microbial activity against pathogenic bacterial strain including *Bacillus subtilis* and *Mycobacterium phlei*[46]. The growth of fungi *Bassidiobolus ranarum* and *Bassidiobolus haptosporus* is strongly inhibited by leaf extract[47]. Another research on fixed oil and extract of *Moringa* against bacterial strains *Escherichia coli* (*E. coli*), *Staphylococcus aureus* (*S. aureus*), *Pseudomonas aeruginosa* (*P. aeruginosa*), *Bacillus stearothermophilus*, green algae (*Scenedesmus obliquus*) and Sabin vaccine (poliovirus type 1 and herpes simplex virus type 1 were performed). The antimicrobial activity was confirmed with varying degree ranging from resistant for *P. aeruginosa* to sensitive for *Bacillus stearothermophilus*[48,49]. The oil of *Moringa* possesses both antifungal and antibacterial activities[50,51]. Comparative study of seed extract for antimicrobial activity against bacteria (*B. subtilis*, *E. coli*, *Pasturella multocida* and *S. aureus*) and fungi (*Rhizopus solani* and *Fusarium solani*) validated that *B. subtilis* and *Pasturella multocida* are the most sensitive strains and cations such as K, Na, Mg and Ca** affect their activity[52]. In the latest study, *Moringa* extracts were validated to be inhibitory in dose dependent manner against *B. subtilis*, *E. coli*, *S. aureus* and *P. aeruginosa*[53]. Another comparative study on the efficacy of *Moringa* steam distillate against bacteria and fungi observed that it has more inhibitory effect against *E. coli*. It was followed by the inhibitory effect for *S. aureus*, *P. aeruginosa*, *Klebsiella pneumonia* and *B. subtilis*. Among fungi, it shows strong inhibition for *Aspergillus niger* and then followed by *Aspergillus oryzae*, *Aspergillus nidulans* and *Aspergillus terreus*[54]. Compared to the previous studies on the inhibitory effect of *Moringa* on the *Candida albicans* and *P. aeruginosa*, another recent reseach using ethanol extract of flower, seeds and leaves validates antimicrobial potential against *E. coli*, *Enterobacter* spp., *Klebsiella pneumonia*, *P. aeruginosa*, *Proteus mirabilis*, *Salmonella typhi*, *Streptococcus* spp. *S. aureus* and *Candida albicans*[55]. *Moringa* contains many other specific phytoconstituents that have antibacterial activity such as 4-(a-L-rhamnopyranosyloxy)benzyl isothiocyanate, 4-(4’-O-acetyl-a-L-rhamnopyranosyloxy) benzyl isothiocyanate, 4-(a-L-rhamnopyranosyloxy) benzyl glucosinolate and niazimicin, benzyl isothiocyanate[7,56]. Other phytochemicals especially anthonine and spirochirin are reported from the root of *Moringa* that have antibacterial activity. Anthonine possesses a strong inhibitory effect for *Vibrio cholerae*[47].

5.2.2. Anti-inflammatory activity

Various plant parts of *Moringa* have significant anti-inflammatory activity. The root has strong anti-inflammatory effects on rat paw edema induced by carrageenan[57]. The root methanol extract inhibited carrageenan which induced rat paw edema in a dose dependent manner, when administered orally. Another study validated that *n*-butanol extract of *Moringa* seed inhibited the inflammation in ovalbumin-induced airway in guinea pigs[58]. The betterment of inflammation produced during different chronic disease is possible with the significant anti-inflammatory activity of *Moringa* bioactives[59,60].
5.2.3. Anthelmintic activity
Moringa leaves and flowers are able to control parasitic worms[61]. The ethanol extract of leaves is reported to inhibit Pheterima posthuma (Indian earthworm)[62].

5.2.4. Analgesic activity
The analgesic activity is reported for several Moringa species. Considerable analgesic activity was reported for Moringa fruit in experimental animals[63]. Furthermore, marked analgesic activity is reported for alcoholic extract of Moringa seeds and leaves[64].

5.2.5. Antipyretic and cholesterol lowering activity
The leaves of Moringa put forth direct effect for stabilizing blood pressure. Moringa mustard oil glycosides, thiocarbamate glycosides and nitrile are compounds leading to blood pressure lowering effect in leaves[6]. In addition, β-sitosterol was reported effective in lowering cholesterol level from the rats serum when fed with high fat diet[65].

5.2.6. Antipyretic activity
Several studies reported that Moringa has significant antipyretic activity. The antipyretic effect of Moringa seeds extracts was assessed in different solvents (ethanol, petroleum ether, ether and ethyl acetate) using yeast induced hyperpyrexia method in rats taking paracetamol as a control. Ethanol and ethyl acetate extracts are reported to have significant antipyretic activity[66,67].

5.2.7. Antidiabetic activity
The leave extract of Moringa has potent antidiabetic activity as it can lower blood sugar levels within 3 h after ingestion[68,69]. In modeled type-II diabetes, Moringa leaves decrease the level of blood glucose in Goto-Kakizaki and Wister rats[31]. Dark chocolate polyphenols and other polyphenols were used for developing the mechanistic model for studying the antidiabetic effect of Moringa as they are considered to be responsible for hypoglycemic activity[70,71]. The leaves of Moringa contain a significant amount of polyphenols including quercitin-3-glycoside, kaempferol glycosides, rutin and other polyphenols which confirmed its antidiabetic activity[30]. The potential antidiabetic activity of Moringa can be commercialized by transferring into conventional drugs through the development of suitable technology[72].

5.2.8. Antioxidant activity
A considerable number of plants have been evaluated for their antioxidant potential. Moringa is an important module in this category as it is a rich source of antioxidants[73,74]. Extract obtained from fruits, seeds and leaves of Moringa have antioxidant potential[31,75]. One of the comprehensive studies on antioxidant property of Moringa leaves reported that ethanol and methanol extracts of Moringa have the highest antioxidant activity with 66.8% and 65.1% respectively[76-78]. The major bioactives of phenolics such as quercitin and kaempferol are responsible for antioxidant activity[22,78]. Kaempferol and quercitin showed antioxidant activity on hepatocyte growth factor induced by phosphorylation (IC<sub>50</sub> value: 12 and 6 µmol/L respectively)[79]. Radical scavenging for antioxidant potential of Moringa seeds is comparable to palm oil[80].

5.2.9. Antitumor activity
Moringa is a potent antitumor plant and several bioactives of anticancer potential have been identified and isolated. Among bioactives, niazimicin was found to have potent anticancer activity[81]. The inhibition of teleocidin B-4-induced Epstein-Barr virus activation was shown by niazimicin[82]. Cytotoxicity through sea urchin eggs assay, brine shrimp lethality assay, hemolysis assay and MTT assay using tumor cell lines is also reported for this plant. A study on human multiple myeloma cell lines reported the cytotoxic effects of leaves[83-85]. Moringa seeds have anticancer activity as they affect hepatic carcinogen metabolizing enzymes[86,87].

5.2.10. Hepatoprotective activity
Moringa leaves ethanol extract showed potent effect against liver damage in rats induced by rifampicin, pyrazinamide and isoniazid (antitubercular drugs). The effect of Moringa on glutamic oxaloacetic transaminase (aspartate aminotransferase), glutamic pyruvic transaminase (alanine aminotransferase), alkaline phosphatase and bilirubin levels in serum and lipid peroxidation levels in liver mediates its hepatoprotective activity[36,88]. Moreover, the chlorofom and methanol extract of Moringa flowers showed potent hepatoprotective activity against liver damage induced by CCl<sub>4</sub>, in Albino rats. Quercitin in Moringa flowers also provides significant protection against liver damage[89]. Moringa seed extract was found to reduce liver fibrosis. Moringa seed extract controls CCl<sub>4</sub> induced by serum globulin and aminotransferase elevation. Immunohistochemical studies revealed that liver fibrosis was retracted by Moringa plant[90].

5.2.11. Anti-ulcer effects
Different parts of Moringa plant, especially root and leave, contain several compounds with spasmylocytic activity. 4-[(α-L-rhamnosylxybenzyl)-o-methyl thiocarbamate is affected possibly through Ca channel blockade, niazinin B, niazinin A, niazimicin, etc. with bradycardia and hypotensitive effect. The spasmylocytic activity supports traditional use of this plant in gastrointestinal disorder[91]. Moringa methanol extract provides significant protection against indomethacin acetylsalicylic acid and serotonin induced gastric in experimental rat[92]. Anti-ulcer effect of Moringa leaves aqueous extract is also reported on adult Holtzman Albino rats[93].

5.2.12. Cardiac stimulant activity
Several studies reported that all parts of Moringa are somewhat cardiac stimulant. Moringinine, an alkaloid, in the root bark of Moringa tree is considered as cardiac stimulant[93]. A comparison of Moringa leaves extract with atenolol on serum cholesterol, triglyceride level and blood glucose level on body weight and heart weight of rats induced with adrenaline indicated that cardiovascular parameters are significantly changed. Ara <i>et al.</i> reported Moringa leaf extract as hypolipidemic, lowering heart weight, body weight, serum cholesterol level and serum triglyceride level on experimental animals[94]. Anti-atherosclerotic and hypolipidemic effect of Moringa leaves was analyzed using simvastatin as control[3,74]. Moringa caused cardioprotective effects in male Wistar albino rats in isoproterenol-induced myocardial infarction. The treatment of Moringa played a favorable inflection on biochemical enzymatic parameters (creatine kinase-MB, glutathione
peroxidase, superoxide dismutase, lactate dehydrogenase, catalase). Moreover, it prevented ultra-structure perturbation and histopathological damage caused by isoproterenol due to induced myocardial infarction.

5.2.13. Anti-asthmatic activity

Moringine, a Moringa plant alkaloid, resembling in action with ephedrine is used for asthma[95]. The effectiveness of seed kernels of Moringa against bronchial asthma was reported. The study validated a significant decrease in the sternness of asthma and coexisting respiratory function improvement[96].

5.2.14. Ocular diseases

Moringa leaves and pods consumption is effective against eye problems and helpful in preventing night blindness. Vitamin A nutrition was improved and cataract development was delayed by ingestion of leaves[97]. As a supplementary food, Moringa for its potential as vitamin A source was accepted by integrated child development scheme supplementary food[98].

6. Conclusions

M. oleifera, a multipurpose tree, is cheaply and easily cultivated and grown in various regions of the world. M. oleifera plant is the most credible but cheap alternative for not only curing a large number of chronic diseases but also for providing worthy nutrition. Pharmacologically, this study reported the effects of this plant including antimicrobial, antioxidant, anti-inflammatory and analgesic, hypotensive, anti-ulcer, antiarthritic, cardioprotective and wound healing activity. This review emphasizes the further exploration regarding pharmacological activities of M. oleifera to isolate the active compounds for novel herbal medicine. Utilization of this plant can help poor countries to fight against poverty, hunger, malnutrition and diseases. In addition, by exporting its various products foreign exchange could be earned.

Conflict of interest statement

We declare that we have no conflict of interest.

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