



Effects of Bioactive Compounds from *Moringa oleifera* for Treating Human Diseases

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ABSTRACT

The use of phytoconstituents as therapeutic is more advantageous as compared to conventional drugs since these are purely natural compounds with no side effects. Moringa oleifera is considered a miracle plant as it offers numerous health benefits due to the presence of phytochemicals like saponins, phenolics, tannins, alkaloids, polyphenols, terpenes, tannins, etc. It is not only rich in secondary metabolites but is also a source of primary metabolites like carbohydrates, lipids, proteins, minerals & vitamins making it a superfood.

Key words: *Moringa oleifera, phytochemicals, anti-cancer, anti-diabetic, anti-ulcer*

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INTRODUCTION

***Moringa oleifera* – An Introduction**

Moringa oleifera is native to the Himalayas, it belongs to the family Moringaceae and genus *Moringa*, also known as drumstick tree, horseradish tree, Gagawandalahai, Kelor, Marango, Mulangay, Benzolive & Guiligandja. It is globally referred to as a miracle plant owing to its pharmacological properties and associated health benefits [1]. Worldwide 13 species of *Moringa* are cultivated out of which *Moringa oleifera* is most common. Other species are *M. peregrine*, *M. arborea*, *M. longituba*, *M. pygmaea*, *M. stenoplana*, *M. rivae*, *M. borziana*, *M. ovalifolia*, *M. ruspoliana*, *M. hildebrandtii*, *M. concanesis* & *M. drouhardii* [2]. *Moringa oleifera* is indigenous to sub-Himalayas, Afghanistan, Bangladesh & Pakistan, it grows well in both tropical and subtropical areas [3]. It can easily be cultivated in hot, humid as well as dry areas with less fertile soil, it is quite adaptable to all climates [4]. It can reach a height of 15 meters with a diameter of 20-40 cm [5]. Charak Sanhita and African folk medicine also describe its importance in treating various ailments, these records are as old as 5000 years [6].

For its growth, the plant requires a temperature range of 25-35°C, net rainfall of 250-3000mm, slightly acidic or alkaline sandy or loamy soil. Seeds germinate in 5-12 days and are sown 2 cm deep into the soil [7]. Though it is native to South Asia but is not being cultivated in other parts of the world like Central America, the Philippines, Africa & Cambodia [8].

It has been in use since 150 B.C due to its health-related benefits and its cultivation boosted during the 1990s since then it is a plant of great economic importance. It is used as Lactagogue in countries like Senegal and Benin, it helps in boosting milk production in lactating mothers [9]. *Moringa oleifera* is rich in vitamin C, vitamin A, calcium, protein, potassium and iron [10]. It can serve as a great source of nutrition & all of its vegetative structures are edible like its leaves, flowers, seeds, fruits, stems & pod shells, these vegetative structures are rich in proteins, fiber, phenolic compounds, carbohydrates, functional peptides, fatty acids, etc. [11].

Moringa oleifera serves as a source of nutrients and phytoconstituents, every vegetative structure of the plant is rich in some nutrients which favor the utilization of the complete plant. Leaves contain a total of 35 bioactive compounds including carotenoids (trans-leutin, β -carotene, zeaxanthin), ascorbic acid, vitamin A & B complex essential amino acids, linoleic acid, potassium & dietary antioxidants [12,13]. Leaves contain more α -carotene than carrots & spinach, about 4X & 13X more respectively [14]. The content of vitamin C is also higher as compared to oranges and pork meat [15]. The stem of *Moringa oleifera* is rich in alkaloids like moringine & moringinine, β -sitosterol, 4-hydroxymellein & octacosanoic acid [16]. Flowers contain sucrose, alkaloids, amino acids & flavonoids like isoquercitrin, rhamnetin [17]. The seeds of this plant are a source of proteins and lipids. Seeds are rich in essential and semi-essential amino acids like histidine, phenylalanine, tyrosine, isoleucine, threonine & leucine. Fermentation of seeds is helpful in improving the content of these amino acids. Low content of glucose, fructose and sucrose

makes them suitable to be consumed as diabetic food. Seeds contain about 2.04% Provitamin A, 0.94% Vitamin B and other minerals like K, P, Zn, Na, Ca & Mg, but the content of the biomolecules varies from place to place [18]. Seeds have low MUFA but higher PUFA content [19].

1. Taxonomic Classification & Botanical Attributes of *Moringa oleifera*

Moringa oleifera is useful in all forms, its fruit is in the form of a pod which is woody, 20-60 cm long and it opens into two leaflets when ripened. About 12-35 seeds are present in one pod. Seeds are trivalent and possess longitudinal wings. Leaves are pinnate and are divided into leaflets. Leaflets are arranged on rachis. Flowers are arranged in axillary panicles and axillary inflorescence. Flowers are bisexual, & zygomorphic with five petals, stamens, and sepals. Flowers are fragrant, white, or cream-colored. Stems are straight, erect and roots are tuberous [20].

Table 1. Taxonomic Classification [21]

| | |
|----------------------|-----------------|
| Kingdom | Plantae |
| Subkingdom | Tracheobionta |
| Superdivision | Spermatophyta |
| Division | Magnoliophyta |
| Class | Magnoliopsida |
| Subclass | Dilleniidae |
| Order | Capparales |
| Family | Moringaceae |
| Genus | <i>Moringa</i> |
| Species | <i>oleifera</i> |

2. Bioactive Compounds Present in *Moringa oleifera*

The composition of bioactive compounds present in *Moringa oleifera* depends on the climatic conditions, its origin whether wild or cultivated, maturity at the time of harvesting, processing methods adopted post-harvesting and the quality of soil used for cultivation [22].

Each vegetative part of *Moringa* is a storehouse of both micro & macronutrient.

Table 2. Nutritional Composition of vegetative parts of *Moringa oleifera*

| Vegetative Part | Nutritional Composition | Medicinal Uses |
|------------------------|--|--|
| Flowers | Have high content of MUFA (16-30%), Potassium, Calcium, amino acids & essential oils [13] | The presence of MUFA confers anti-arthritic & hypocholesterolemic properties and essential oils can effectively cure cold & urinary system related disorders [23]. |
| Pods | Have high content of glucans & polysaccharides (32%), the content of fatty acids like linoleic acid, oleic acid & palmitic acid is also high, pods are rich in PUFA and potassium [13]. | Since pods are rich in PUFA they can be used in the diet of obese patients |
| Leaves | They are rich in all sorts of macro & micronutrients ranging from primary metabolites like vitamin A, B, C, β -carotene, essential amino acids, carbohydrates, potassium, calcium, magnesium, zinc, copper, iron, phosphorus, sterols to secondary metabolites like alkaloids, tannins, carotenoids, terpenes, glucosinolates, isothiocyanates, phenolic acids, polyphenols & steroids [25]. | The presence of primary and secondary metabolites in <i>Moringa</i> leaf enables its use for the treatment of diseases like dementia, epilepsy, STD, cardiovascular diseases, hypertension, cancer, digestive issues, hepatotoxicity, etc. [24]. |
| Seeds | They are rich in fatty acids (40%) like oleic acid and other phytochemicals like benzyl isothiocyanate, sitosterol, niazirin & benzyl carbamate [26]. | These phytochemicals can reduce cholesterol levels and can improve metabolism & cellular functions [27]. |
| Roots | Have higher tannin, oxalate, carbohydrate, arginine, vitamin C, lysine & sodium content. They are also rich in alkaloids like moringinine [28]. | The presence of alkaloids in bark confers anti-oxidant and anti-ulcer properties [29]. |

3. Applications in Health Care

Other than just macronutrients *Moringa oleifera* is rich in micronutrients and other secondary metabolites. Phenolics, alkaloids, flavonoids & glycosides present in *M. oleifera* exhibit antimicrobial, anti-diabetic, hepatoprotective, anti-inflammatory, anticancer, cardioprotective & anti-oxidant properties [30, 31, 32 and 33]. *Moringa oleifera* contains enough bioactive compounds that can treat about 300 diseases, thus this plant is often referred to as panacea.

3.1. For treatment of Diabetes

Diabetes is a metabolic disorder it can either be type 1 or type 2, Type 1 is associated with the production of nonfunctional insulin or no insulin production, this hormone is required to keep the blood glucose within the required limits. In the case of type 2 diabetes, the body doesn't respond to insulin, β cells are responsible for sensing glucose levels and signaling for the production of insulin but in the case of type 2 diabetes, the beta cells become nonfunctional or doesn't function as intended [34]. *Moringa oleifera* is rich in flavonoids (rutin, kaempferol & quercetin), phenolic acids (caffeoylquinic & chlorogenic acid) these compounds exhibit antihyperglycemic properties, they are inhibitors of SGLT1 in the mucosa of the duodenum & jejunum thus they reduce the absorption of glucose in the intestine [35].

Leaf extract of *M. oleifera* exhibits antihyperglycemic activity by inhibiting the activity of intestinal sucrose, α -glucosidase & pancreatic α -amylase. Terpenoids present in leaf extract stimulate β cells to secrete preformed insulin [36]. *Moringa* can also be used for the treatment of diabetes-related complications such as atherosclerosis, retinopathy, nephropathy, etc. Hyperglycemia accelerates the transcription of cytokines like IL-6 & interferons, expression of cell adhesion molecules on the surface endothelium of arteries results in transendothelial migration causing inflammation in arteries leading to atherosclerosis but *Moringa oleifera* is anti-atherogenic in nature [16].

Antioxidant Activity

Antioxidants scavenge free radicals that can cause cell damage, inflammation & oxidative stress; flavonoids, ascorbic acids & polyphenols are antioxidants that are present in seeds, flowers & leaves of *Moringa*; polyphenols like ellagic acids, niacinimicin A, gallic acids, tocopherols, etc. confer high anti-oxidative activity to plant due to their H donating ability [37]. *Moringa* extract inhibits the oxidation of plasma LDL by reducing the initiation and escalation of lipid peroxidation. Treatment with *Moringa* extract affects the acetylation of protein present in mitochondria, it accelerates the activity of complex 1 & reduces the activity of UCP2 (Uncoupling Protein 2), thus playing a major role in modulating mitochondrial respiratory chain producing antiatherosclerotic and hypolipidaemic effects [38].

3.2. For Ulcer and other Digestion related Issues

Bisphenols and flavonoids present in *Moringa oleifera* aid in reducing ulcer index in case of ethanol-induced, aspirin-induced, pylorus ligation induced & cold stress induced ulcers. 50% ethanolic leaf extract of *Moringa oleifera* was used for the treatment of ulcers. This extract not only prevented recurrence but also reduced the secretion of acid-pepsin [39]. At doses of 350 mg & 500 mg acidity in case of gastric ulcers can be reduced by 85.13% & 86.15% respectively [40].

3.3. Anti-Inflammatory Activity

In *Moringa oleifera* presence of bioactive compounds like quercetin inhibits the activation of NF-KB, this produces an anti-inflammatory effect [40]. *Moringa* extract can inhibit the expression of mRNA and concentration of iNOS (inducible Nitric Oxide synthase), IL-6, Cyclooxygenase-2 & TNF- α in a dose-dependent way [42]. *Moringa* extract can also inhibit the production of cytokines like TNF- α , IL-8 & IL-6 resulting from LPS & smoking, extract can also reduce the expression of genes associated with inflammation [43].

Bioactive compounds responsible for anti-inflammatory effects are moringine, vanillin, tannins, flavonoids, β -sitosterol, phenols, 9-octadecenoic acid, hydroxymellein, β -sitostenone, alkaloids & moringinine [44].

3.4. Neuropharmacological Activity

Moringa oleifera leaf extract alters the electrical activity and monoamine levels in brain, it is also rich in Vitamin C & Vitamin E which can significantly improve memory in patients with Alzheimer's [45]. It is a potent neuroprotectant. When blood flow to the brain is obstructed it results in cerebral ischemia causes lipid peroxidation & reperfusion it accelerates the formation of reactive oxygen species. Phytochemicals present in *Moringa oleifera* affect the production of ROS and can be used in the treatment of dementia. Leaf extracts reduce the activity of acetylcholine esterase which improves memory [46].

3.5. Hepatoprotective Activity

Due to the presence of high phenolic content in its leaves and seeds, *Moringa oleifera* can protect the liver from oxidation, damage & toxicity. Its oil can restore the normal activity of liver enzymes which helps in the proper immobilization of fat; the phytoconstituents like β -sitosterol, rutin, glycosides & quercetin prevent the oxidation of lipids [47]. *Moringa* seed extract blocks the production of alanine

aminotransferase (ALT) & aspartate aminotransferase (AST), their levels are indicators of liver health; it also protects the liver against Carbon Tetrachloride induced fibrosis [48]. Ethanolic extract protects the liver against damage induced by rifampicin, pyrazinamide & isoniazid which are antitubercular drugs, these extracts reduce the serum levels of bilirubin, alkaline phosphatase, alanine aminotransferase & aspartate aminotransferase [41].

3.6. For Treatment of Asthma & other Respiratory Issues

Asthma is a chronic inflammation of the airways, as a result of which airways get narrowed causing difficulty in breathing; Moringa seed extract not only acts as a bronchodilator but also exhibits anti-inflammatory & anti-microbial properties, it not only reduces the complication of the disease but also inhibits the hypersensitive reactions. Ethanolic extract prepared from seeds also reduces the production of interleukins in the bronchoalveolar passage [49].

3.7. For treatment of Cardiovascular Disorders

Moringa leaf extract can effectively reduce the serum cholesterol levels, LDL (Low-Density Lipoprotein), VLDL (Very Low-Density Lipoprotein), CPR (Cholesterol Phospholipid Ratio), phospholipids & triglycerides. Leaf extract is also rich in β -sitosterol which has cholesterol lowering activity [50].

Moringa seed extract can effectively stabilize blood pressure. A study was conducted by Adefegha et al., 2019, [51] In albino male rats with hypertension were fed with Moringa leaves, a drastic effect was observed in the systolic and diastolic blood pressure of these rats, it reduced to a normal level. Bioactive compounds present in Moringa reduce the activity of enzymes like arginase, angiotensin-1 converting enzyme & acetylcholinesterase which stabilizes the blood pressure.

Moringa leaf powder also helps in the reduction of total body weight, cholesterol & triglyceride levels by downregulating the expression of mRNA for leptin & resistin, upregulating expression of adiponectin gene [52].

3.8. Effects on Reproductive System

Leaves of Moringa contains about 11,300-23,000 IU of Retinol which is essential for maintaining the normal physiology of the reproductive system, it is required for the growth of the embryo and its development, cell differentiation, development of reproductive organs & immunity [53]. Aqueous leaf extract of Moringa aids in the development of testis, epididymis & seminal vesicle, it aids in lumen formation and increases the diameter of seminiferous tubule [54].

3.9. Antimicrobial Activity

Roots of Moringa contain benzyl isothiocyanate & pterygospermin, these bioactive compounds exhibit antibiotic activity against *H. pylori* (bacterium causing peptic ulcers) & other microbes [55]. Aqueous extracts of leaf, flowers and pods are effective against several strains of Gram-positive bacteria (*Staphylococcus aureus*), Gram-negative bacteria (*E. coli*, *S. typhi*, *E. aerogenes*, *S. typhimurium* & *Shigella spp.*) & fungal strains (*Aspergillus niger*, *A. paracitic*, *A. flavus*, *Candida albicans*, *Trichoderma harzanium*, *Fusarium oxysporum*) [56,57]. Chloroform extract of Moringa leaf is effective against Gram-positive bacterial strains whereas ethanolic extract is effective against fungal strains [58].

Methanolic extract prepared from leaves can inhibit the growth of microbes responsible for UTI (Urinary Tract Infection) caused by *Staphylococcus aureus*, *E. coli* & *K. pneumoniae* [59].

3.10. For Treatment of Cancer

Cancer accounts for one in six deaths worldwide and in India, at present, there are around 2.4 million cases. Smoking, alcohol consumption, sedentary lifestyle, improper diet are all leading causes of cancer. For its treatment chemotherapy, radiotherapy & surgery are common approaches but these methods are expensive and have numerous side effects [24]. The effect of Moringa extract was studied on melanoma tumor models and it was observed that ethanolic extracts obtained from fruit & leaves of Moringa delayed the growth of tumors, it also inhibited the proliferation of tumors in lung cells [59].

Bioactive compounds like carbamates, nitrile glycosides, quercetin, thiocarbamate, niazimicin & kaempferol are associated with the anti-tumor properties of Moringa. These bioactive compounds scavenge ROS present in tumor cells, which results in cell apoptosis [61].

3.11. Anti-Diuretic Activity

Campesterol, avenasterol, hydrochlorothiazide, stigmasterol & β -sitosterol are bioactive compounds abundantly present in roots, seeds, bark, leaves & flowers of Moringa, they increase the removal of waste from our body by increasing the urine output. Among all vegetative structures, pods exhibited higher diuretic and antihypertensive activity [62].

4. Toxic Effects Associated with *Moringa oleifera*

Moringa oleifera is a storehouse of all essential nutrients, but recent studies have indicated miracle plant does contain some mutagens especially roasted seeds which can cause major damage to the liver, kidney & circulatory system. 4-(α -Iramnopyranosyloxy)-benzyl glucosinolate is a potential mutagen, it increases the number of micronucleated polychromatophilic erythroblasts, the presence of these cells in the body is

indicative of genotoxicity. Consumption of plants containing high content of saponins reduces the bioavailability of Zn & Mg in the body, leaves of *Moringa* contain a high level of saponins [63].

5. Conclusion

The review focuses on the potential of *Moringa oleifera* for the treatment of various human diseases like cardiovascular diseases, inflammatory diseases, digestive system disorders, neurodegenerative disorders, cancer, etc. Primary areas that require research are the anti-cancer, anti-inflammatory & anti-diabetic properties of *Moringa*. It has been observed that the environmental conditions have a significant effect on the phytochemical content of vegetative parts of the plant, further research is required in this field as well. Till now only the nutritional aspect of *Moringa* is studied in more detail but more research is required for detailed study of its negative impacts on health.

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