

Phytoconstituents and Pharmacological Activities of Moringa Oleifera: A Review

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Abstract

'Miracle Tree, Moringa oleifera is known for its remarkable nutritional and medicinal properties, derived from a rich array of phytochemicals. Niacin, niaziminin, caffeic acid, quercetin, moringin and many medicinally important phytochemicals have been found in this plant. This review provides detailed information about these phytochemicals and presents the current knowledge of Moringa oleifera, explore the extensive range of biological activities associated with the plant, from anti-inflammatory and hepatoprotective effects to its antimicrobial and anticancer potential. Additionally, this paper discusses future research perspectives and potential applications in pharmaceutical industries. This comprehensive review aims to serve as a cornerstone reference for researchers, healthcare professionals, and students, emphasizing the need for continued exploration of this versatile plant.

Keywords: Moringa oleifera, anti-inflammatory, phytoconstituents, anticancer, antimicrobial, hepatoprotective activities.

Introduction

Moringa oleifera, also known as horse radish tree, ben oil tree, drumstick tree and miracle tree, is highly significant plant because of its extraordinary properties [1]. Due to its high nutritional values, Moringa oleifera has been proved to be a valuable food source. It has now been a part of Indians' routine diet. Various therapeutic properties make it medicinally important tree. Traditional medicines use almost every component of this tree including leaves, stem, seeds, roots, pods, etc. Its leaves are notably rich in vital nutrients consisting of vitamin A, C, E; minerals like potassium, calcium, iron, magnesium, manganese, zinc, copper along with a wide range of phytochemicals.

Moringa oleifera is medium sized tree native to sub Himalayan regions of India, Asia, Africa and tropical areas of world. It is also cultivated in North East Pakistan, North East Bangladesh, West Indies, etc. It is a fast growing tree and drought resistant tree that can easily adapt in harsh and unfavourable environment [1]. This tree is generally 10 m in height with soft trunk and gummy bark [2]. Flowers are white and have pleasant fragrance. Various parts of Moringa oleifera tree has been

Phytoconstituents and Pharmacological Activities of Moringa Oleifera: A Review

Jyoti Pathak & Neeraj Kanwar & Prof. Sangeeta Bhargava

studied for several pharmacological actions. Leaves have been reported to possess antifungal, anti microbial, anti inflammatory, diuretic and analgesic properties.

Taxonomy

Kingdom	-	Plantae
Subkingdom	-	Tracheobiota
Super division	-	Spermatophyta
Division	-	Magnoliophyta
Class	-	Magnoliopsida
Subclass	-	Dillenidae
Order	-	Capparales
Family	-	Moringaceae
Genus	-	Moringa
Species	-	Oleifera Lam

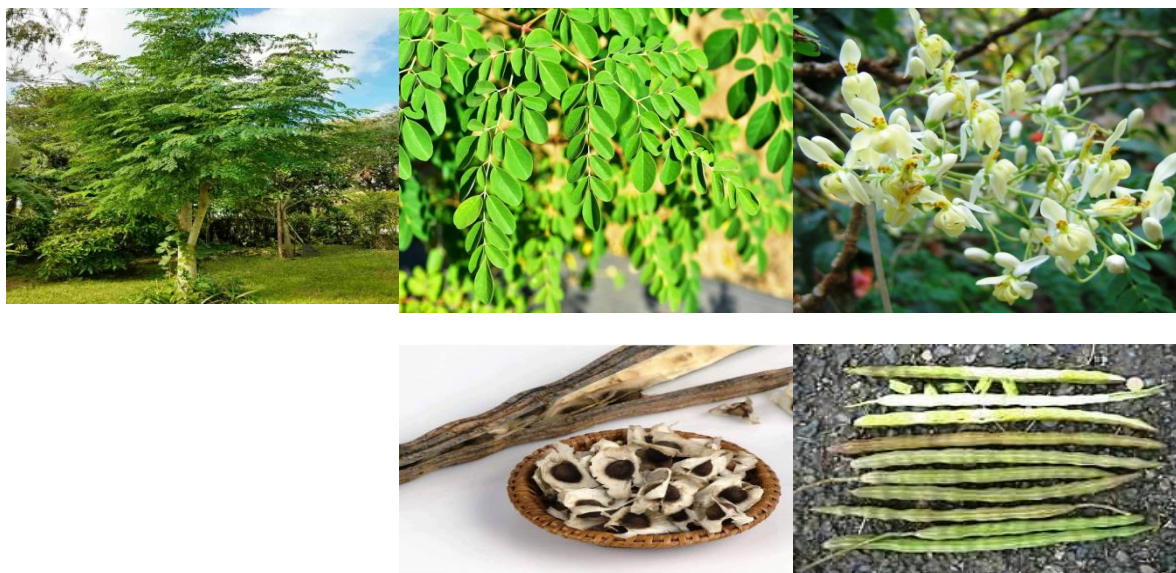


Fig. 1 : Moringa Oleifera - Tree, Leaves, Flowers, Seeds and Beans

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Jyoti Pathak & Neeraj Kanwar & Prof. Sangeeta Bhargava

Phytochemical Constituents

Moringa oleifera is a rich source of various bioactive compounds, making it a valuable plant for both nutritional and medicinal purposes. The polar and non-polar extracts of Moringa leaves and seeds have been shown to contain a wide range of phytochemicals, including glucomoringin, vitexin, moringin, quercetin, kaempferol, and beta-sitosterol-3-O-glucoside. These compounds are crucial for the plant's diverse pharmacological activities. High-Performance Liquid Chromatography (HPLC) analysis has revealed the presence of phenolic acids such as gallic acid, ellagic acid, chlorogenic acid, and ferulic acid. Additionally, flavonoids like quercetin, isoquercetin, kaempferol, and rutin have been identified in Moringa leaves. These compounds are well-known for their antioxidant properties, which help in neutralizing free radicals and protecting the body from oxidative stress. Moringa leaves are particularly abundant in unique compounds such as niazirin, niazirin, niaziminin A and B, epicatechin, and ortho-coumaric acid [2]. These phytochemicals contribute to the plant's anti-inflammatory, antimicrobial, and anticancer activities, making Moringa a versatile component in traditional and modern medicine. The stem of Moringa oleifera contains other significant phytochemicals, including cholest-5-en-3-ol, stigmasterol, gamma-sitosterol, and tricosanoic acid [3]. These compounds are known for their roles in maintaining cellular structure and function, and they also contribute to the plant's anti-inflammatory and cardiovascular protective properties. Ethanolic extracts of Moringa oleifera leaves have been reported to contain oleol, satol, ocenol, and decanoic acid as major components [4]. These compounds are vital for the plant's antimicrobial activity and are also involved in metabolic processes that support overall health. The flowers of Moringa oleifera are rich in B-sitosterone and kaempferol-3-rutinoside, both of which have been found to exhibit significant antioxidant and anti-inflammatory effects. These phytochemicals contribute to the plant's ability to prevent and manage chronic diseases, including cardiovascular disorders and cancer. The seeds of Moringa are notable for containing moringyne, 4-(alpha-L-rhamnosyloxy) benzyl isothiocyanate, and a variety of amino acids. Benzyl isothiocyanate, in particular, is also present in the roots and is recognized for its potent anticancer and antimicrobial properties [5]. These compounds reflect the potential of Moringa seeds and roots as therapeutic agents in the treatment of various diseases. Furthermore, the methanolic extract of Moringa oleifera leaves has shown the presence of rhamnetin, astragalol, marumosiol A, vicienin, luteolin, among others. These compounds are known for their diverse biological activities, including antioxidant, anti-inflammatory, and immunomodulatory effects, which enhance the overall health benefits of Moringa.

Phytoconstituents and Pharmacological Activities of Moringa Oleifera: A Review

Jyoti Pathak & Neeraj Kanwar & Prof. Sangeeta Bhargava

Table 1 : Phytoconstituents found in various parts of *Moringa oleifera*

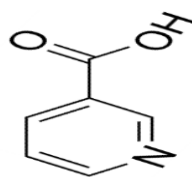
S.No.	Plant Part	Extract	Phytoconstituents
1.	Leaves	Aqueous and alcoholic	4-[(4'-O-acetylalpha-L-rhamnosyloxy)benzyl isothiocyanate, 4-(alpha-1-rhamnopyranosyloxy)-benzylglucosinolate, Apigenin, Ascorbic acid (Vitamin C), Beta-sitosterol, Caffeic acid, Catechin, Chlorogenic acid, Coumaric acid, Epicatechin, Ferulic acid, Flavonoids, Gallic acid, Gamma-tocopherol-2, Hydroxybenzoic acid, Isothiocyanates, Kaempferol, Lutein, Myricetin, Naringenin, Niaziminin, Niaziminin A, Niaziminin B, Niazirin, Niazirin - nitrile glycosides, Pterygospermin, Quercetin, quercetin-3-O-glucoside and quercetin-3-O-(6"-Malonyl-glucoside), Rutin, Sinapic acid, Tannins, Vanillin, Zeatin
2.	Seeds	Aqueous and hydro-alcoholic	4-(alpha-L-Rhamnosyloxy)benzylglucosinolate, Arginine, Benzyl isothiocyanate, Benzylamine, Beta-sitosterol, Campesterol, Ferulic acid, Gallic acid, Glucosinolates, Glutamic acid, Histidine, Leucine, Linoleic acid, Lysine, Oleic acid, Palmitic acid, Phytins, Phytosterols, Proteinases, Saponins, Stearic acid, Stigmasterol, Tocopherol (Vitamin E), Tryptophan
3.	Root	Alcoholic	4-(alpha-L-Rhamnosyloxy)benzylglucosinolate, Aegeline, Alkaloids, Benzyl isothiocyanate, Benzylamine, Beta-sitosterol, Campesterol, Caffeic acid, Coumarins, Flavonoids, Glucosinolates, Kaempferol, Lignin, Niaziminin, Niazimicin, Phenolic acids, Phenylacetoneitrile, Pterygospermin, Quercetin, Saponins, Stigmasterol, Tannins, Terpenoids, Triterpenes, Vanillin
4.	Stem	Aqueous and hydro-alcoholic	Alkaloids, Beta-sitosterol, Caffeic acid, Campesterol, Catechin, Cellulose, Coumarins, Ferulic acid, Flavonoids, Gallic acid, Hemicellulose, Kaempferol, Lignin, Luteolin, Phenolic acids, Phenolic glycosides, Quercetin, Saponins, Stigmasterol, Tannins, Triterpenes, Vanillin, Xyloglucan, Zeatin

Polar and non-polar extracts of *Moringa* leaves and seeds show the presence of glucomoringin, Vitexin, Moringin, Quercetin, Kaempferol, beta-sitosterol-3-o-glucoside, etc. The HPLC analysis indicated the presence of phenolic acids like gallic acid, elegaic acid, chlorgenic acid, ferullic acid and flavanoids like quercetin, isoquercetin, Kaempferol, rutin, etc. *Moringa* leaves have abundance of niazirin, niazirin, niaziminin A, B, epicatechin and ortho-coumaric acid. Cholest-5-en-3-ol, stigmasterol, gamma-sitosterol, tricosanoic acid has been reported to be present in the stem of *Moringa oleifera*. Oleol, Satol, Ocenol, decanoic acid have been reported as the major components of ethanolic extract of *Moringa oleifera* leaves. B-sitosterone and Kaempferol-3-rutinoside has been found in flowers of *Moringa oleifera*. Seeds contain moringyne, 4-(alpha-L-rhamnosyloxy) benzyl

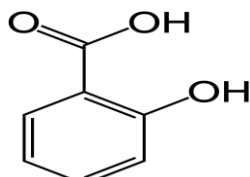
Phytoconstituents and Pharmacological Activities of *Moringa Oleifera*: A Review

Jyoti Pathak & Neeraj Kanwar & Prof. Sangeeta Bhargava

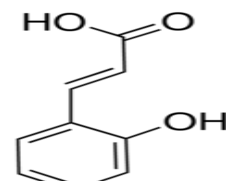
isothiocyanate and some amino acids. Benzyl isothiocyanate has been reported to be present in roots. Methanolic extract of moringa oleifera Leaf also shows the presence of Rhamnetin, Astragalin, Marumosiide A, Vicenin, Luteolin, etc [6].



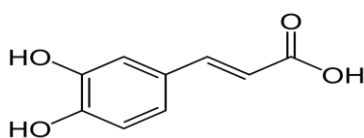
Niacin



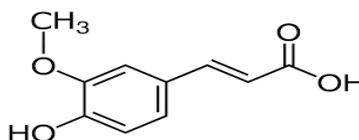
Phenolic Acid



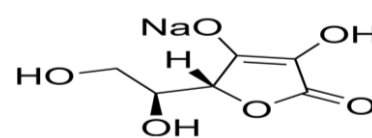
O-Coumaric Acid



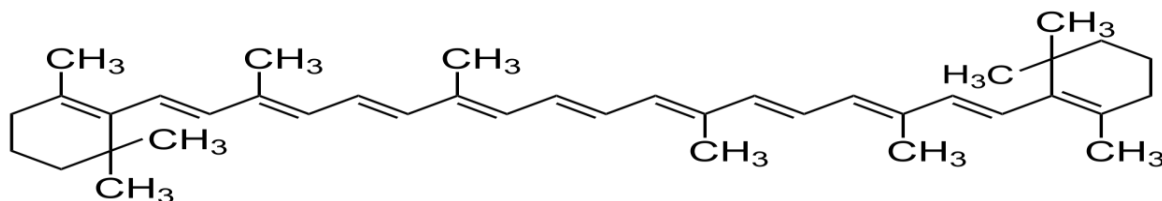
Caffeic Acid



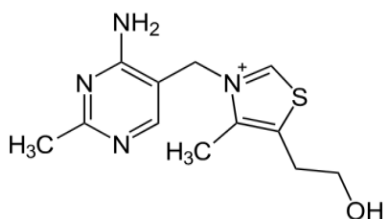
Ferulic Acid



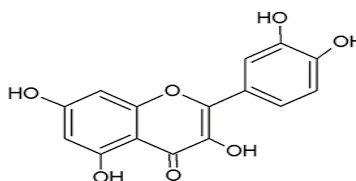
L-Ascorbic Acid



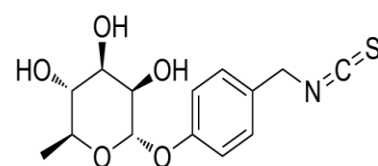
Beta-carotene



Thiamine



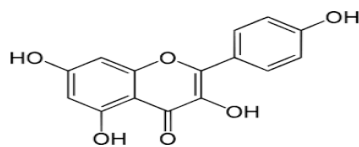
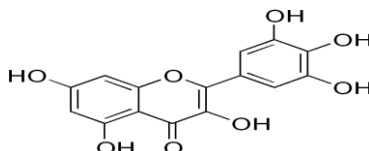
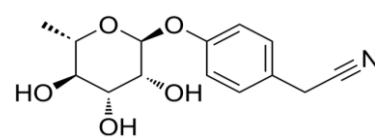
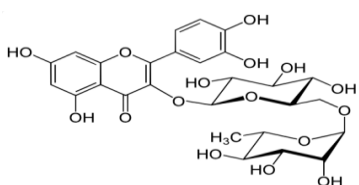
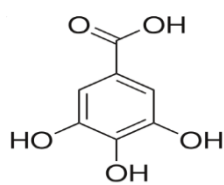
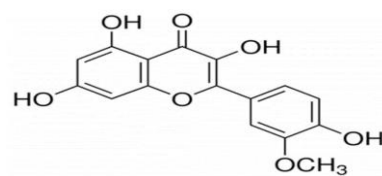
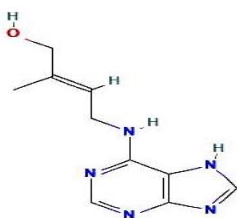
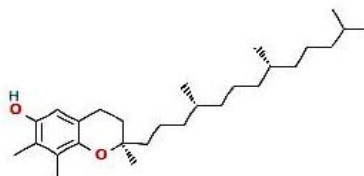
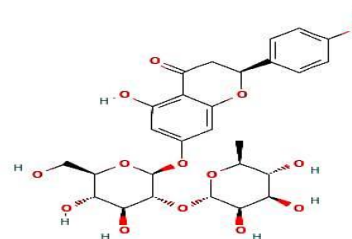
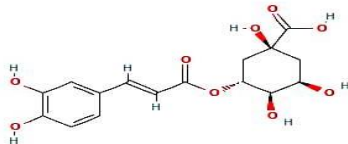
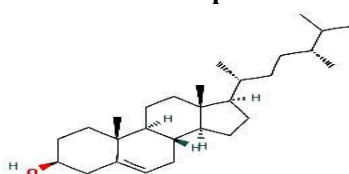
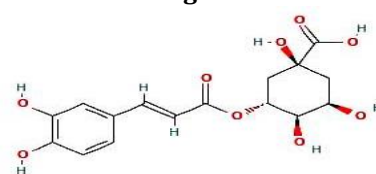
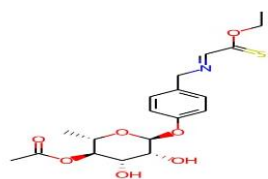
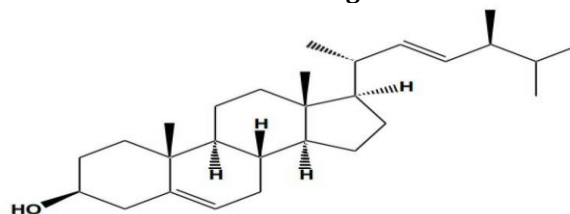
Quercetin



Moringin

Phytoconstituents and Pharmacological Activities of Moringa Oleifera: A Review

Jyoti Pathak & Neeraj Kanwar & Prof. Sangeeta Bhargava

**Kaempferol****Myricetin****Niazirin****Rutin****Gallic Acid****Isorhemnetin****Zeatin****Gamma tocopherol****Naringenin****Apigenin****Campesterol****Chlorogenic acid****Niaziminin B****Stigmasterol**

Phytoconstituents and Pharmacological Activities of *Moringa Oleifera*: A Review

Jyoti Pathak & Neeraj Kanwar & Prof. Sangeeta Bhargava

Pharmacological studies

Moringa leaves are used to treat malaria, pneumonia, bronchitis, hyperglycemia, syphilis and infections of eyes and ear. Many investigations have proved that secondary metabolites found in leaves and other parts of Moringa possess significant pharmacological and therapeutic actions, including antimicrobial anti-asthmatic anti-ulcer, anti-tumour, anti-diabetic, anti-inflammatory, hepatoprotective, cardiovascular and immunomodulatory activities [2],[7,8].

In Moringa oleifera, flavonoids such as quercetin, kaempferol and rutin are abundant. Quercetin, in particular, has been extensively studied for its ability to scavenge free radicals and protect cells from oxidative stress, which is a key factor in the development of chronic diseases like cancer and cardiovascular disorders [9]. Chlorogenic acid, commonly found in coffee, is known for its antioxidant and anti-inflammatory properties. Moringa oleifera contains glucosinolates, sulfur-containing compounds that can be converted into isothiocyanates through enzymatic processes. Isothiocyanates have been shown to exhibit strong anticancer, antimicrobial, and anti-inflammatory properties. Isothiocyanate moringin has been found to induce apoptosis in cancer cells and inhibit the proliferation of harmful bacteria [10]. Moringa oleifera contains several alkaloids including moringine and moringinine, which have been associated with various pharmacological activities such as lowering blood pressure and relaxing muscles. The presence of these alkaloids contributes to the plant's use in treating cardiovascular and respiratory diseases [11]. Moringa oleifera is exceptionally rich in essential vitamins and minerals, including vitamin A, vitamin C, calcium, potassium, and iron. The leaves of the plant contain high levels of beta-carotene (a precursor to vitamin A), which is crucial for maintaining healthy vision and immune function [12]. Vitamin C acts as a powerful antioxidant, protecting the body from oxidative stress and supporting immune health [13]. The high calcium content in Moringa leaves makes it a valuable dietary supplement for bone health [14].

Anti-microbial activity

Antimicrobial activity of ethanolic extracts of leaves, seeds and flowers of Moringa oleifera has been reported to act against E.coli and Candida albicans. Its antifungal and antibacterial potential has also been reported against A.niger and B.subtillus respectively [5].

Anti-oxidant properties

Extracts of Moringa leaves exhibit strong antioxidant activities against free radicals. It provides protection from oxidative damage of bio molecules. Due to high amount of polyphenols, overall combined action of constituting metabolites and hydrogen donating ability; Moringa exhibit high radical scavenging activities [15]. Caffeic acid is another potent antioxidant that helps protect cells from oxidative damage [16]. Highest content of chlorogenic acid, caffeic acid and gallic acid in freeze dried leaves of Moringa exhibit antioxidant properties to a great extent [17].

Anti-cancer Activity

Moringa oleifera is considered as potential source of anti cancerous compounds. Ethanolic extracts of leaves and seeds of Moringa shows potent anti-tumour activity. Isothiocyanates present in it acts as inhibitor of tumour promotion. Similarly thiocarbamates inhibit the growth of tumour.

Phytoconstituents and Pharmacological Activities of Moringa Oleifera: A Review

Jyoti Pathak & Neeraj Kanwar & Prof. Sangeeta Bhargava

Niazimicin found in the leaves of Moringa has significant anticancer activities [2].

Anti-diabetic activities

Moringa leaves have the potential of curing both types of diabetes, i.e. Type I and Type II. Moringa leaves protect beta cells from damage and keep hyperglycemia under control [8].

Chlorogenic acid, commonly found in coffee, is known for its antioxidant and anti-inflammatory properties. It also plays a role in regulating glucose metabolism, making it beneficial for managing diabetes [18].

The hypoglycaemic effect of Moringa oleifera has been well-documented, with studies showing its ability to reduce blood glucose levels and improve insulin sensitivity [19]. This activity is linked to the presence of isothiocyanates, chlorogenic acid, and flavonoids, which enhance glucose uptake in cells and reduce the absorption of glucose in the intestines [20].

Cardioprotective Activity

The plant's high content of antioxidants, such as flavonoids and phenolic acids, helps reduce oxidative stress, a major contributing factor to the development of atherosclerosis and other cardiovascular conditions [21]. Moringa oleifera has also been shown to lower cholesterol levels, reduce blood pressure, and improve lipid profiles, all of which are critical factors in maintaining heart health [22].

Neuroprotective Activity

The plant's high antioxidant content helps protect neurons from oxidative stress, which is a major contributor to neuro degeneration [23]. Moringa oleifera has also been shown to reduce inflammation in the brain, which is associated with the pathogenesis of neurodegenerative diseases [24].

Immunomodulatory Activity

The plant's bioactive compounds, such as flavonoids and saponins, have been shown to stimulate the production of immune cells, including lymphocytes and macrophages, thereby boosting the body's defense mechanisms [25].

Moringa oleifera has also been found to enhance the production of antibodies, which are essential for neutralizing pathogens and preventing infections. Additionally, the plant's antioxidant properties help protect immune cell from oxidative damage, ensuring their proper functioning [26].

Hepatoprotective Activity

Moringa oleifera exhibits significant hepatoprotective properties due to its rich content of flavonoids and phenolic acids. These compounds help to reduce oxidative stress, enhance detoxification processes, and protect liver cells from toxin-induced damage. Moringa leaf extracts have been shown to prevent liver injury from toxins like alcohol and pharmaceuticals. In rats, Moringa oleifera leaf extract. Was found to significantly reduce the levels of serum liver enzymes (ALT and AST), which are indicators of liver damage. It also improved antioxidant enzyme activities, such as superoxide dismutase (SOD) and catalase, thereby reducing oxidative stress [27].

Phytoconstituents and Pharmacological Activities of Moringa Oleifera: A Review

Jyoti Pathak & Neeraj Kanwar & Prof. Sangeeta Bhargava

Anti-Ulcer Activity

Moringa oleifera is known for its potent anti-ulcer properties. It enhances the production of gastric mucus, reduces gastric acid secretion, and inhibits pepsin activity, all of which contribute to its anti-ulcerogenic effects. Studies involving animal models have shown that Moringa leaf extract reduces the incidence of gastric ulcers induced by stress, alcohol, and NSAIDs. This protective effect is largely attributed to its high flavonoid content, which strengthens the gastric mucosal barrier [28].

Antihypertensive Activity

The antihypertensive effects of Moringa oleifera are well-established, primarily through vasodilation, reduced vascular resistance, and diuresis. Bioactive compounds in Moringa, such as nitrile glycosides and isothiocyanates, are known to influence these processes. Several studies report that Moringa leaf extract significantly lowers systolic and diastolic blood pressure, likely due to calcium ion channel inhibition, which relaxes blood vessel smooth muscle cells [29].

Anti-Asthmatic Activity

Moringa oleifera has been traditionally used to treat respiratory conditions like asthma. Its anti-asthmatic effects are due to its bronchodilatory properties and anti-inflammatory effects. Compounds such as quercetin and isothiocyanates in Moringa relax bronchial muscle, reduce airway resistance, and improve airflow. A study on asthma patients reveals that Moringa leaf extract significantly improved lung function and reduced the frequency of asthma attacks[30]. Additionally, Moringa was also found to inhibit the degranulation of mast cells, which play a key role in allergic reactions and asthma by releasing histamines and other inflammatory mediators. By stabilizing these cells, Moringa reduces the severity of allergic asthma symptoms, making it a valuable natural remedy for asthma management [31].

Future trends

The increasing interest in herbal medicine reflects a broader shift towards natural treatments that leverage the body's immune system through multi-target and multi-pathway synergistic effects. This approach not only mobilizes the human immune system but also supports its ability to achieve a radical cure. Extensive toxicity studies have confirmed the safety of many herbal medicines, including Moringa oleifera, making them an attractive option for treating various diseases. In recent years, medicinal plants like Moringa oleifera have gained recognition as viable strategies for disease prevention and treatment, especially given their low toxicity and high efficacy.

Moringa oleifera is mentioned extensively in traditional texts for its diverse medicinal functions, which range from treating common ailments to preventing chronic diseases. As a medicinal and edible plant, Moringa oleifera has garnered significant global attention due to its broad pharmacological potential. One of the challenges and opportunities lies in studying this exotic species using traditional Chinese medical theory to better understand the pharmacological actions and mechanisms of its medicinal constituents. This integration of traditional knowledge with modern research could pave the way for novel therapeutic applications.

The future development of Moringa oleifera as a dietary supplement or adjunct therapy will

Phytoconstituents and Pharmacological Activities of Moringa Oleifera: A Review

Jyoti Pathak & Neeraj Kanwar & Prof. Sangeeta Bhargava

likely focus on improving formulation design and preparation methods. This includes the selection of appropriate delivery systems that enhance the stability, safety, and efficacy of the bioactive compounds. Currently, *Moringa oleifera* is available in common dosage forms such as granules, tablets, and capsules. However, innovative preparations like nano-pharmaceuticals are being explored to improve the bioavailability of *Moringa*'s active ingredients. Despite this progress, there remains a significant opportunity to develop other novel formulations that can better harness the plant's medicinal properties.

Further development should consider the biopharmaceutical properties of *Moringa oleifera*, such as solubility and permeability, to ensure that its medicinal substances are effectively delivered *in vivo*. The use of advanced delivery systems, such as nano-pharmaceuticals, can significantly enhance the safety, stability, and bioavailability of these preparations, making them more effective in treating a range of conditions.

The future of *Moringa oleifera* in both medicinal and dietary contexts is promising, but it requires continued research and innovation. By clarifying the biopharmaceutical properties and developing advanced formulations, *Moringa oleifera* can be more effectively utilized as a natural remedy in modern healthcare.

Conclusion

Moringa oleifera is a versatile plant with a multitude of health benefits attributed to its rich phytochemical profile and wide range of biological activities. This comprehensive review has highlighted the plant's potential in modern medicine, nutrition, and sustainable agriculture, emphasizing its role in addressing global health challenges. Further research is essential to fully unlock the therapeutic potential of *Moringa oleifera* and to explore its applications in various scientific and medical fields. By understanding of this "Miracle Tree" we can pave the way for innovative solutions to many health and environmental issues.

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Phytoconstituents and Pharmacological Activities of *Moringa Oleifera*: A Review

Jyoti Pathak & Neeraj Kanwar & Prof. Sangeeta Bhargava

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Phytoconstituents and Pharmacological Activities of *Moringa Oleifera*: A Review

Jyoti Pathak & Neeraj Kanwar & Prof. Sangeeta Bhargava

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Phytoconstituents and Pharmacological Activities of Moringa Oleifera: A Review

Jyoti Pathak & Neeraj Kanwar & Prof. Sangeeta Bhargava