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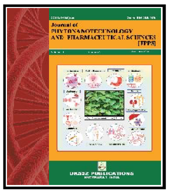

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# Comprehensive review of *Moringa oleifera* Lam.: Phytochemistry, pharmacokinetics, and therapeutic applications

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**Abstract**

*Moringa oleifera* Lam., a fast-growing and drought-tolerant tree native to South Asia, has attracted considerable attention for its therapeutic potential. This review outlines its phytochemistry, pharmacokinetics, and pharmacological properties. Over 110 bioactive compounds have been identified in different plant parts, including flavonoids, phenolic acids, alkaloids, glucosinolates, and vitamins. Pharmacokinetic studies indicate rapid absorption and significant systemic exposure of key constituents such as vicenin-2, kaempferol-3-O-rutinoside, isoquercetin, and niazirin following oral intake. Preclinical data show neuroprotective effects in Alzheimer's models, where aqueous and methanolic leaf extracts improve memory and reduce oxidative stress. The plant also shows potential in respiratory disorders, demonstrating antiasthmatic and anti-inflammatory effects in animals. *M. oleifera* exhibits anticancer activity by promoting apoptosis through reactive oxygen species generation. Its anti-inflammatory action involves suppression of pro-inflammatory cytokines and NF-κB signaling. Cardioprotective and hepatoprotective benefits have been observed, with extracts improving hemodynamics, reducing myocardial injury, and mitigating liver damage. Additionally, it exerts antidiabetic effects by preserving β-cells and enhancing glucose metabolism. Clinical studies further support its use, particularly for bronchial asthma. In conclusion, *M. oleifera* is a promising medicinal plant with diverse pharmacological actions, warranting further research to clarify its mechanisms and develop standardised clinical formulations.

## 1. Introduction

As interest in herbal therapy has grown in recent years, *Moringa oleifera* Lam. has become more and more well-known in developed nations. Comparing it to traditional synthetic medications, its natural origin and perceived lower risk of side effects are the main factors driving this trend (Paikraand Gidwani, 2017). Herbal treatments and their active ingredients are essential components of traditional medical systems, including homoeopathy, naturopathy, Siddha, Ayurveda, and Unani. According to estimates, over 70% of Indians rely on these non-allopathic systems for their medical requirements (Paikraand Gidwani, 2017). However, the prevalence of traditional medicine varies by location in the world. *M. oleifera,* also known as the drumstick tree or miracle tree, is a rapidly growing, drought-resistant species native to South Asia, particularly Afghanistan, Bangladesh, India, and Pakistan (Fuglie, 1998; Varmaniand Garg, 2014). Its remarkable adaptability has facilitated its widespread cultivation across tropical and subtropical regions. The genus *Moringa*, belonging to the family Moringaceae, comprises 13 known species. Of them, *M. oleifera* has been studied the most. This is mostly because of its significant medicinal, nutritional, and financial potential (Varmani and Garg, 2014; Gandji *et al.,* 2018; Chaudhary and Chaurasia, 2017).

In ancient Ayurvedic literature, *M. oleifera* was used in topical remedies, such as poultices, to cure wounds, infections, and other conditions. The leaves are a unique example of a complete plant-based protein supply because they contain all nine essential amino acids and are notable for their high protein concentration. According to phytochemical studies, *M. oleifera* has about 110 bioactive components, including minerals like calcium and iron as well as important vitamins A, B1, B2, C, and E (Abd Rani *et al.,* 2018; Dhakad *et al.,* 2019). Numerous secondary metabolites, including alkaloids, flavonoids, terpenes, phenols, steroids, glycosides, saponins, tannins, and gums, are also shown to be present (Lopez-Teros*et al.,* 2017; Lin *et al.,* 2019; Islam *et al.,* 2020). Preclinical studies suggest that *M. oleifera* may have anti-inflammatory, antibacterial, antidiabetic, and anticancer effects (Leone *et al.,* 2015; Dhakad *et al.,* 2019; Mahmood *et al.,* 2010; Bhattacharya *et al.,* 2018). Although, there is now little scientific evidence to support these uses, it has historically been used to treat the symptoms of pneumonia, diarrhoea, and urinary tract infections. The seeds and leaves have noteworthy antibacterial and biosorbent capabilities, which lend credence to their possible applications in food preservation and water purification. Since *M. oleifera* thrives in nutrient-deficient soils, especially rocky terrain, it is a crop that may be grown in dry and semi-arid environments (Alegbeleye, 2018).

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## 2. Taxonomical classification and synonyms

*M. oleifera* is taxonomically classified under the Kingdom Plantae, Sub-Kingdom Tracheobionta, Super Division Spermatophyta, Division Magnoliopsida, Sub-Class Dilleniidae, Order Capparales, Family Moringaceae, Genus *Moringa,* and Species *oleifera* (Chaudhary and Chaurasia, 2017; Paikra and Gidwani, 2017; Makkenakuppe *et al.,* 2015).

*M. oleifera* is known by various names across different languages and traditional systems. In Latin, it is referred to as *Moringa oleifera*; in Sanskrit as Subhanjana; in Hindi as Saguna or Sainjna; in Gujarati as Suragavo; in Tamil as Mulaga or Munaga; in Malayalam as Murinna or Soanjna; in Punjabi as Sainjna or Soanjna; in Unani as Sahajan; in Ayurveda as Haritashaaka, Raktaka, or Akshiva; in Arabic as Rawag; in French as Morungue; in Spanish as Angela, Ben, or *Moringa*; in Chinese as *La ken*; and English, it is commonly known as the Drumstick tree or Horseradish tree.

## 3. Morphological description of *M. oleifera*

*M. oleifera* is a fast-growing, deciduous to semi-evergreen tree, typically reaching 10-12 m in height with a straight trunk measuring 20-46 cm in diameter. The bark is thick, corky, and whitish-grey, while younger shoots display a purplish or greenish-white pubescence. It has a spreading, open, umbrella-shaped crown composed of drooping, fragile branches. The foliage is feathery, formed by pinnately or tripinnately compound leaves 20-60 cm long, bearing numerous small, elliptic to ovate leaflets approximately 1-2.5 cm long and 0.3-0.6 cm wide. Flowers are bisexual and fragrant, measuring around 1-2.5 cm in diameter, with five unequal, thin-veined, yellowish-white petals and five fertile stamens plus several staminodes. They are borne in lax, drooping racemes of 10-25 cm. Fruit develops into pendant, three-sided woody capsules, commonly known as "drumsticks," typically 20-45 cm long (occasionally reaching up to 90-120 cm), that dehisce into three valves at maturity. Each capsule contains about 20-30 globose brown seeds (~1 cm diameter), each enveloped with three papery wings and dispersed by wind and water. The root system is deep, often with a well-developed taproot and lateral roots; the bole is generally single-stemmed but occasionally forked near the base (Pareek *et al.,* 2023).

## 4. Phytochemistry of *M. oleifera*

Numerous elements of *M. oleifera* and its isolated synthetic compounds have been the subject of extensive research. More than 90 bioactive compounds with noteworthy therapeutic effects have been identified as a result of research conducted within the genus *Moringa.* Proteins and amino acids, phenolic acids, carotenoids, alkaloids, glucosinolates, flavonoids, sterols, terpenes, tannins, saponins, fatty acids, glycosides, and polysaccharides are just a few of the chemical classes that are represented by these isolated compounds (Masarkar *et al.,* 2024; Paikra and Gidwani, 2017; Krawczyk *et al.,* 2022).

In particular, flavonoids and phenolic acids are known to be highly concentrated in *M. oleifera* leaves. There are flavonoids with significant medicinal benefits, such as quercetin, catechin, myricetin, and kaempferol, as well as known phenolic acids such as cinnamic acid, sinapic acid, gentisic acid, gallic acid, ferulic acid, protocatechuic acid, vanillin, caffeic acid, o-coumaric acid, p-coumaric acid, and epicatechin (Paikra and Gidwani, 2017). In significant quantities, *M. oleifera* leaves contain lutein, a pigment with well-known antioxidant qualities. Most of the plant's medicinal benefits are ascribed to the many bioactive substances found in its leaves. Gas chromatography-mass spectrometry (GC-MS) analysis has identified several key constituents that are responsible for its medicinal value. These include palmitoyl chloride, cis-vaccenic acid, 5-O-acetyl-thio-octyl, pregna-7-dien-3-ol-20-one, γ-sitosterol, β-1-rhamno-furanoside, and tetradecanoic acid (Ayon Bhattacharya, 2014).

The leaves of *M. oleifera* contain two newly identified alkaloids, marumoside A and marumoside B, while aurnatiamide acetate has been isolated from the roots. Additionally, the stem contains the alkaloids moringa and moringinine. Glucomoringin, the predominant glucosinolate in *M. oleifera*, serves as a major source of these bioactive compounds. β-sitosterol-3-O-β-D-galactopyranoside, a sterol glycoside, has been identified in the bark, whereas β-sitosterol is present in both seeds and leaves. The plant also contains significant levels of terpenes and their derivatives (Sahakitpichan *et al.,* 2011; Abd Rani *et al.,* 2018).

## 5. Pharmacokinetic properties of *M. oleifera*

A recent pharmacokinetic study by Abdou *et al. (*2024) investigated several water-soluble phytoconstituents from *M. oleifera* leaves, including vicenin-2, kaempferol-3-O-rutinoside, and isoquercetin. These compounds reached peak plasma concentrations approximately 0.5 h after oral administration. Among them, vicenin-2 exhibited the highest peak concentration and notable bioavailability. In contrast, kaempferol-3-O-rutinoside demonstrated a significantly longer biological half-life, indicating prolonged systemic presence (Wang *et al.,* 2024). In another study, Wang *et al.* (2022) used UPLC-MS/MS to evaluate the pharmacokinetics of niazirin, a key bioactive compound in *M. oleifera*, in rats. The results revealed rapid absorption, with Cmax occurring around 0.4 hpost-dose. The elimination half-life ranged from 2.74 to 3.36 h, while the mean residence time (MRT) was approximately 3.6 h. Niazirin displayed substantial systemic exposure following oral administration, with an absolute bioavailability between 46.78% and 52.61%.

## 6. Pharmacological and therapeutic properties of *M. oleifera*

According to Mughal *et al.* (1999), *M. oleifera* has long been prized for its many therapeutic qualities, which are well acknowledged in both Ayurvedic and Unani medicine systems. Below is a detailed description of the pharmacological actions and therapeutic potential linked to various components of *Moringa* (Mughal *et al.,* 1999).

### 6.1 Neuroprotective effects of *M. oleifera* in Alzheimer's disease

Behavioral assessment using the radial Y-maze task demonstrated that the aqueous extract of *M. oleifera* leaves conferred neuropro tection in a colchicine-induced mouse model of Alzheimer's disease (Ganguly *et al.,* 2010b). This protective effect was associated with altered brain monoamine levels and changes in electrical activity (Ganguly and Guha, 2008). Another study reported that the toluene-ethyl acetate fraction of the methanolic leaf extract exhibited significant nootropic activity (Mohan *et al.,* 2005). The high content of vitamins C and E in the leaf extract has also been shown to positively influence memory function in Alzheimer's disease patients (Akramand Nawaz, 2017; More *et al.,* 2016).

## 6.2 Effect of *M. oleifera* on respiratory health

The methanolic leaf extract of *M. oleifera* (MOLE) has shown notable anti-asthmatic and anti-inflammatory effects in an ovalbumin-induced asthma model in guinea pigs (Suresh *et al.,* 2020). Enriched with flavonoids, phenolics, glycosides, and tannins, MOLE was administered at doses of 250 mg/kg and 500 mg/kg, with dexamethasone serving as a reference drug. Treatment with MOLE enhanced pulmonary function parameters, including respiratory rate and tidal volume, indicating bronchodilatory activity. Additionally, it significantly reduced total leukocyte counts in both blood and bronchoalveolar lavage fluid, as well as histamine levels in lung tissue, suggesting inhibition of mast cell degranulation. Histopathological evaluation demonstrated reduced inflammation, attenuated basement membrane thickening, and preserved airway structure. These results support the anti-asthmatic efficacy of MOLE *via* anti-inflammatory, antihistaminic, and bronchodilatory mechanisms.

## 6.3 Anticancer potential of *M. oleifera*

Cancer is a prevalent illness that causes about one out of every seven deaths globally. It is projected that 2.4 million cases in India may be avoided. Several risk factors, such as smoking, physical inactivity, and radiation exposure, have been discovered, despite the fact that the precise causes of cancer are sometimes unknown (Nair *et al.,* 2015). Radiation, chemotherapy, and surgery are some of the expensive and frequently unfavourable side effects of cancer therapies. *M. oleifera* natural origin, safety, and dependability at prescribed dosages have made it a promising anticancer drug. Research has indicated that *Moringa* possesses antineoproliferative qualities that efficiently impede the proliferation of cancerous cells. The leaves have demonstrated strong anticancer properties in both soluble and solvent preparations. According to a study, *Moringa* may also have antiproliferative effects *via* inducing reactive oxygen species (ROS) in cancer cells. The elevation of two important apoptotic pathway enzymes, caspase-3 and caspase-9, indicates that an increase in ROS causes apoptosis. (Tiloke *et al.,* 2013; Jung, 2014; Leelawat and Leelawat, 2014). Furthermore, *M. oleifera* has the potential to be an excellent anticancer drug since the reactive oxygen species (ROS) it produces are selective, focusing primarily on cancer cells (Tiloke *et al.,* 2013). Glutathione-S-transferase, an enzyme that regulates antioxidant activity by suppressing the expression of certain antioxidants, was also shown to be upregulated by *Moringa* extracts.

Although, it is commonly known that anticancer drugs work by causing reactive oxygen species (ROS), these drugs should additionally target antioxidant enzymes for maximum effectiveness (Liou and Storz, 2010). It's interesting to note that extracts from moringa leaves have anticancer and antioxidant qualities, including the capacity to produce ROS. We still do not fully understand how these seemingly incompatible outcomes interact. Benzyl isothiocyanate, niazimicin, and glucosinolates are the main substances found in *Moringa* leaves that have anticancer properties (Hermawan *et al.,* 2012). Benzyl isothiocyanate (BITC) has been especially associated with anticancer properties among them. Research has shown that BITC stimulates the production of intracellular ROS, which results in the death of cancer cells. This may be one of the reasons for *Moringa's* strong anticancer properties (Nakamura *et al.,* 2002; Miyoshi *et al.,* 2004; Lee and Shacter, 1999).

## 6.4 Effect of *M. oleifera* in inflammatory disorders

Various parts of *M. oleifera*, including the leaves, pods, flowers, and roots, have demonstrated significant anti-inflammatory activity. Tan *et al.* (2015) reported that 4-[2-O-acetyl-α-L-rhamnosyloxy) benzyl] thiocyanate, a compound isolated from the plant, exhibited nitric oxide inhibitory effects in RAW 264.7 macrophage cells. Additionally, compounds such as 1,3-dibenzylurea and aurantiamide acetate, isolated from the roots, have been shown to suppress TNF-α production (Cuéllar-Núñez *et al.,* 2021). According to Bhattacharya *et al.* (2018), the plant's anti-inflammatory properties are attributed to a number of active phytochemicals, such as tannins, phenols, alkaloids, flavonoids, carotenoids, β-sitosterol, vanillin, and moringin (Bhattacharya *et al.,* 2018). Furthermore, it was demonstrated that *M. oleifera* fruit extract prevented nuclear factor kappa B (NF-κB) from translocating, although its chloroform extract was lethal at higher concentrations (500-1000 µg/ml) (Abdel-Daim *et al.,* 2020). Furthermore, treatment with *M. oleifera* leaf extract in a mouse model of atopic dermatitis led to decreased expression of retinoic acid-related orphan receptor γT, thymic stromal lymphopoietin, and mannose receptor mRNA in ear tissues, as observed in studies involving human keratinocytes (Choi *et al.,* 2016).

## 6.5 Effect of *M. oleifera* on cardiovascular health

Freeze-dried aqueous and alcoholic extracts of *M.oleifera* have exhibited cardioprotective effects in animal models of isoproterenol-induced myocardial infarction (Nandave *et al.,* 2009). Chronic administration of *M. oleifera* effectively mitigated hemodynamic disturbances and elevated the activity of key enzymes, including superoxide dismutase (SOD), catalase, lactate dehydrogenase, glutathione peroxidase, and creatine kinase (Nandave *et al.,* 2009). The butanolic extract, rich in N-α-rhamnopyranosylvincosamide, demonstrated potent antioxidant properties in rats with isoproterenol-induced cardiac necrosis, significantly reducing inflammation and myocardial injury (Panda *et al.,* 2013). Moreover, *M. oleifera* leaves notably reduced cholesterol levels in hypertensive rats, with compounds such as niazirminA, niazirmin B, and niazimincin likely contributing to these protective effects (Bhattacharya *et al.,* 2018).

## 6.6 Hepatoprotectivepotential of *M. oleifera* in liver disorders

Moringa flowers contain a number of flavonoids, including quercetin, kaempferol, isoquercetin, and rhamnetin. Of these, quercetin is thought to be the one that has hepatoprotective properties (Upadhyay *et al.,* 2015). A low dose of the methanolic extract changed the hepato-renal and haematological profiles, causing notable modifications in the levels of serum LPO, bilirubin, alkaline phosphatase, plasma cholesterol, and aminotransferase. Higher dosages, however, had an impact on blood urea nitrogen, non-protein nitrogen levels, total bilirubin, and decreased clotting time (Mishra *et al.,* 2011). By lowering AST, ALT, and ALP levels in Sprague-Dawley rats with acetaminophen-induced liver damage, *Moringa* demonstrated hepatoprotective benefits equivalent to those of the common medication silymarin (Sharifudin *et al.,* 2013). Lower serum aminotransferase activity and globulin levels demonstrated the seeds' ability to prevent liver fibrosis brought on by carbon tetrachloride (Hamza, 2010). Because of the inclusion of alkaloids, quercetin, kaempferol, flavonoids, ascorbic acid, and benzyl glucosinolates, regular dietary treatment of *Moringa* extract for 21 days dramatically reduced liver damage (Bhattacharya *et al.,* 2018).

### 6.7 Antidiabetic properties of *M. oleifera*: Effects on glucose metabolism and pancreatic β-cells

According to reports, *Moringa* can effectively treat both type 1 and type 2 diabetes. The lack of insulin synthesis, a hormone necessary for sustaining appropriate blood glucose levels, is a hallmark of type 1 diabetes. Contrarily, β-cell dysfunction, in which the cells are unable to accurately monitor glucose levels, may cause type 2 diabetes by impairing insulin signaling and raising blood glucose levels (Cerf, 2013). Extensive research has demonstrated the antidiabetic potential of *M. oleifera*. One study reported that aqueous extracts of *M. oleifera* were effective in managing insulin resistance in type 2 diabetic rats, as well as in streptozotocin (STZ)-induced type 1 diabetes models (Divi *et al.,* 2012). In a separate investigation, administration of *Moringa* seed powder to STZ-induced diabetic rats resulted in a significant reduction in fasting blood glucose levels (Al-Malkiand El Rabey, 2015). Additionally, treatment with approximately 500 mg/kg of *Moringa* seed powder enhanced serum levels of antioxidant enzymes, suggesting that its antioxidant constituents may mitigate the oxidative stress-induced damage to pancreatic β-cells caused by STZ exposure (Mbikay, 2012). STZ induces ATP dephosphorylation reactions and promotes the activity of xanthine oxidase, leading to the formation of superoxides and reactive oxygen species (ROS) in β-cells (Wright *et al.,* 2006). In hyperglycemic conditions, β-cell destruction occurs, allowing excess glucose to enter the mitochondria, which then produces reactive oxygen species. Since β-cells contain a low level of antioxidant enzymes, this oxidative stress results in apoptosis of the β-cells (Kaneto *et al.,* 1999; Prentki and Nolan, 2006). Type 2 diabetes mellitus is the ultimate result of hyperglycemia brought on by this decrease in insulin production. Antioxidants known to scavenge reactive oxygen species (ROS) include flavonoids like quercitrin and other phenolic substances. According to the theory, the flavonoids found in Moringa protect the β-cells and aid in controlling hyperglycemia by scavenging the ROS produced by mitochondria (Kamalakkannan and Prince, 2006; Al-Malkiand El Rabey, 2015). Diabetes causes retinopathy, nephropathy, and atherosclerosis, among other problems. These conditions can be avoided by using *Moringa*. Advanced glycation end products (AGEs) are created when blood glucose and proteins interact in hyperglycemia. AGEs bind to their receptor (RAGE), which is expressed on the surface of immune cells, triggering the upregulation of pro-inflammatory cytokines such as interleukin-6 and interferons. At the same time, the artery endothelial surface expression of cell adhesion molecules occurs (Aronson and Rayfield, 2002). This encourages the migration of transendothelial cells, which results in arterial inflammation and atherosclerosis. According to Chumark *et al.* (2008), *Moringa* is used as an anti-atherosclerotic agent, and its antioxidant qualities are responsible for its anti-atherogenic benefits.

## 7. Clinical trials

*M. oleifera* has been the subject of 25 clinical investigations to date, 19 of which have been finished. Nine of thesestudies assessed *M. oleifera* as a component of a dietary intervention, with the remaining studies concentrating on medication therapies specific to the illness. All things considered, the research showed how well *Moringa* works to treat diseases like HIV infection, chronic renal disease, malnutrition, and reproductive health. The important significance of *M. oleifera* as an antiasthmatic agent was highlighted by a clinical investigation. In this study, bronchial asthma symptoms were treated by *M. oleifera* seed kernels. Blood samples and respiratory parameters were taken both before and after the three weeks of treatment, and participants were chosen based on inclusion and exclusion criteria. For three weeks, patients received a dose of 3 g of the dry powder extract twice a day, with instructions to consume it with water. Using a rating system, symptoms were categorized as severe, moderate, or mild. The findings demonstrated an increase in respiratory function and a decrease in symptoms, suggesting that *Moringa* seeds are a useful treatment for bronchial asthma (Sathyavathi *et al.,* 2011).

## 8. Conclusion

*M. oleifera*, a rapidly growing tree native to South Asia, has attracted considerable interest for its broad therapeutic potential. Phytochemical analyses have identified more than 110 bioactive constituents across various parts of the plant, including flavonoids, phenolic acids, alkaloids, glucosinolates, and essential vitamins. Pharmacokinetic studies indicate that key compounds are rapidly absorbed and exhibit significant systemic availability following oral administration. A wide range of preclinical studies has demonstrated its neuroprotective, anti-asthmatic, anti-inflammatory, anticancer, cardioprotective, hepatoprotective, and antidiabetic effects. Moreover, clinical trials have substantiated its efficacy, particularly in managing bronchial asthma. Overall, *M. oleifera* emerges as a highly promising medicinal plant with multifaceted pharmacological properties, warranting further investigation to establish standardized therapeutic formulations and explore its full clinical potential.

## Conflict of interest

The authors declare no conflicts of interest relevant to this article.

## References


**Abd Rani, N. Z.; Husain, K. and Kumolosasi, E. (2018).** *Moringa* genus: A review of phytochemistry and pharmacology. Front. Pharmacol., **9**:108.

**Abdel-Daim, M. M.; Khalil, S. R.; Awad, A.; Abu Zeid, E. H.; El-Aziz, R. A. and El-Serehy, H. A. (2020).**Ethanolic extract of *Moringa oleifera* leaves influences NF-κB signaling pathway to restore kidney tissue from cobalt-mediated oxidative injury and inflammation in rats. Nutrients, **12**(4):1031.

**Abdou, K. H.; Moselhy, W. A.; Mohamed, H. M.; El-Nahass, E. S. and Khalifa, A. G. (2019).** *Moringa oleifera* leaves extract protects titanium dioxide nanoparticles-induced nephrotoxicity via Nrf2/HO-1 signaling and amelioration of oxidative stress. Biol. Trace Elem. Res., **187**(1):181-191.

**Akram, M. and Nawaz, A. (2017).** Effects of medicinal plants on Alzheimer's disease and memory deficits. Neural Regen. Res., **12**(4):660-670.

**Alegbeleye, O. O. (2018).** How functional is *Moringa oleifera*? A review of its nutritive, medicinal, and socioeconomic potential.Food Nutr. Bull., **39**(1):149-170.

**Al-Malki, A. L. and El Rabey, H. A. (2015).** The antidiabetic effect of low doses of *Moringa oleifera* Lam. seeds on streptozotocin-induced diabetes and diabetic nephropathy in male rats. Biomed. Res. Int., **2015**(1):381040.

**Aronson, D. and Rayfield, E. J. (2002).** How hyperglycemia promotes atherosclerosis: Molecular mechanisms. Cardiovasc. Diabetol., **1**:1-10.

**Ayon Bhattacharya, A. B.; Goutam Ghosh, G. G.; Divya Agrawal, D. A.; Sahu, P. K.; Sanjay Kumar, S. K. and Mishra, S. S. (2014).** GC-MS profiling of ethanolic extract of *Moringa oleifera* leaf. Int. J. Pharm. Bio. Sci., **5**(4):263-75.

**Bhattacharya, A.; Tiwari, P.; Sahu, P. K. and Kumar, S. (2018).** A review of the phytochemical and pharmacological characteristics of *Moringa oleifera*. J. Pharm. Bioall. Sci., **10**(4):181-191.

**Cerf, M. E. (2013).** Beta cell dysfunction and insulin resistance. Front. Endocrinol., **4**:37.

**Chaudhary, K. and Chaurasia, S. (2017).** Neutraceutical properties of *Moringa oleifera*: A review. Eur. J. Pharm. Med. Res., **4**(4):646-655.

**Choi, E. J.; Debnath, T.; Tang, Y.; Ryu, Y. B.; Moon, S. H. and Kim, E. K. (2016).** Topical application of *Moringa oleifera* leaf extract ameliorates experimentally induced atopic dermatitis by the regulation of Th1/ Th2/Th17 balance. Biomed. Pharmacother., **84**:870-877.

**Chumark, P.; Khunawat, P.; Sanvarinda, Y.; Phornchirasilp, S.; Morales, N. P.; Phivthong-Ngam, L. and Pongrapeeporn, K. U. S. (2008).** The *in vitro* and *ex vivo* antioxidant properties, hypolipidaemic and antiatherosclerotic activities of water extract of *Moringa oleifera* Lam. leaves. J. Ethnopharmacol., **116**(3):439-446.

**Cuellar-Núñez, M. L.; De Mejia, E. G. and Loarca-Piña, G. (2021).** *Moringa oleifera* leaves alleviated inflammation through downregulation of IL-2, IL-6, and TNF-α in a colitis-associated colorectal cancer model. Food Res. Int., **144**:110318.

**Dhakad, A. K.; Ikram, M.; Sharma, S.; Khan, S.; Pandey, V. V. and Singh, A. (2019).** Biological, nutritional, and therapeutic significance of *Moringa oleifera* Lam. Phytother. Res., **33**(11):2870-2903.

**Divi, S. M.; Bellamkonda, R. A. M. E. S. H. and Dasireddy, S. K. (2012).** Evaluation of antidiabetic and antihyperlipidemic potential of aqueous extract of *Moringa oleifera* in fructose fed insulin resistant and STZ induced diabetic Wistar rats: A comparative study. Asian J. Pharm. Clin. Res., **5**(1):67-72.

**Fuglie, L. J. (1998).** Producing food without pesticides: Local solutions to crop pest control in West Africa.

**Gandji, K.; Chadare, F. J.; Idohou, R.; Salako, V. K.; Assogbadjo, A. E. and Kakaï, R. G. (2018).** Status and utilisation of *Moringa oleifera* Lam: A review. Afr. Crop Sci. J., **26**(1):137-156.

**Ganguly, R. and Guha, D. (2008).** Alteration of brain monoamines and EEG wave pattern in rat model of Alzheimer's disease and protection by *Moringa oleifera*. Indian J. Med. Res., **128**(6):744-751.

**Ganguly, R.; Hazra, R.; Ray, K. and Guha, D. (2010).** Effect of *Moringa oleifera* in experimental model of Alzheimer's disease: Role of antioxidants. Ann. Neurosci., **12**(3):33-36.

**Hamza, A. A. (2010).** Ameliorative effects of *Moringa oleifera* Lam seed extract on liver fibrosis in rats. Food Chem. Toxicol., **48**(1):345-355.

**Hermawan, A.; Nur, K. A.; Dewi, D.; Putri, P. and Meiyanto, E. (2012).** Ethanolic extract of *Moringa oleifera* increased cytotoxic effect of doxorubicin on HeLa cancer cells. J. Nat. Remedies., pp:108-114.

**Islam, M. T.; Martins, N.; Imran, M.; Hameed, A.; Ali, S. W.; Salehi, B. and Sharifi-Rad, J. (2020).** Anxiolytic-like effects of *Moringa oleifera* in Swiss mice.Cell. Mol. Biol., **66**(4):73-77.

**Jung, I. L. (2014).** Soluble extract from *Moringa oleifera* leaves with a new anticancer activity. PLoS One., **9**(4):e95492.

**Kamalakkannan, N. and Prince, P. S. M. (2006).** Antihyperglycaemic and antioxidant effect of rutin, a polyphenolic flavonoid, in streptozotocin induced diabetic Wistar rats. Basic Clin. Pharmacol. Toxicol., **98**(1):97-103.

**Kaneto, H.; Kajimoto, Y.; Miyagawa, J. I.; Matsuoka, T. A.; Fujitani, Y.; Umayahara, Y. and Hori, M. (1999).** Beneficial effects of antioxidants in diabetes: Possible protection of pancreatic beta-cells against glucose toxicity. Diabetes, **48**(12):2398-2406.

**Krawczyk, M.; Burzynska-Pedziwiatr, I.; Wozniak, L. A. and Bukowiecka-Matusiak, M. (2022).** Evidence from a systematic review and meta-analysis pointing to the antidiabetic effect of polyphenol-rich plant extracts from *Gymnema montanum*, *Momordica charantia* and *Moringa oleifera*. Curr. Issues Mol. Biol., **44**(2):699-717.

**Lee, Y. J. and Shacter, E. (1999).** Oxidative stress inhibits apoptosis in human lymphoma cells. J. Biol. Chem., **274**(28):19792-19798.

**Leelawat, S. and Leelawat, K. (2014).** *Moringa oleifera* extracts induce cholangiocarcinoma cell apoptosis by induction of reactive oxygen species production. Int. J. Pharmacogn. Phytochem. Res., **6**(2):183-189.

**Leone, A.; Spada, A.; Battezzati, A.; Schiraldi, A.; Aristil, J. and Bertoli, S. (2015).** Cultivation, genetic, ethnopharmacology, phytochemistry and pharmacology of *Moringa oleifera* leaves: An overview. Int. J. Mol. Sci., **16**(6):12791-12835.

**Lin, H.; Zhu, H.; Tan, J.; Wang, H.; Wang, Z.; Li, P. and Liu, J. (2019).** Comparative analysis of chemical constituents of *Moringa oleifera* leaves from China and India by ultra-performance liquid chromatography coupled with quadrupole-time-of-flight mass spectrometry. Molecules, **24**(5):942.

**Liou, G. Y. and Storz, P. (2010).** Reactive oxygen species in cancer. Free Radic. Res., **44**(5):479-496.

**Lopez-Teros, V.; Ford, J. L.; Green, M. H.; Tang, G.; Grusak, M. A.; Quihui-Cota, L. and Astiazaran-Garcia, H. (2017).** Use of a "super-child" approach to assess the vitamin A equivalence of *Moringa oleifera* leaves, develop a compartmental model for vitamin A kinetics, and estimate vitamin A total body stores in young Mexican children. J. Nutr., **147**(12):2356-2363.

**Mahmood, K. T.; Mugal, T. andHaq, I. U. (2010).** *Moringa oleifera*: A natural gift-A review. J. Pharm. Sci. Res., **2**(11):775.

**Mallenakuppe, R.; Homabalegowda, H.; Gouri, M. D.; Basavaraju, P. S. and Chandrashekharaiah, U. B. (2015).** History, taxonomy and propagation of *Moringa oleifera*: A review. Crops, **3**(3.28):3-15.

**Masarkar, N.; Ray, S. K.; Saleem, Z. and Mukherjee, S. (2024).** Potential anticancer activity of *Moringa oleifera* derived bioactive compounds targeting hypoxia-inducible factor-1 alpha in breast cancer.J. Complement. Integr. Med., **21**(3):282-294.

**Mbikay, M. (2012).** Therapeutic potential of *Moringa oleifera* leaves in chronic hyperglycemia and dyslipidemia: A review. Front. Pharmacol., **3**:24.

**Mishra, G.; Singh, P.; Verma, R.; Kumar, S.; Srivastav, S.; Jha, K. K. and Khosa, R. L. (2011).**Traditional uses, phytochemistry and pharmacological properties of *Moringa oleifera* plant: An overview. Der Pharm. Lett., **3**(2):141-164.

**Miyoshi, N.; Uchida, K.; Osawa, T. and Nakamura, Y. (2004).**A link between benzyl isothiocyanate-induced cell cycle arrest and apoptosis: Involvement of mitogen-activated protein kinases in the Bcl-2 phosphorylation. Cancer Res., **64**(6):2134-2142.

**Mohan, M.; Kaul, N.; Punekar, A.; Girnar, R.; Junnare, P. and Patil, L. (2005).**Nootropic activity of *Moringa oleifera* leaves. J. Nat. Remedies., **5**(1):59-62.

**More, S. V.; Kumar, H.; Cho, D. Y.; Yun, Y. S. and Choi, D. K. (2016).** Toxin-induced experimental models of learning and memory impairment. Int. J. Mol. Sci., **17**(9):1447.

**Mughal, M. H.; Ali, G.; Srivastava, P. S. andIqbal, M. (1999).**Improvement of drumstick (*Moringa pterygo sperma* Gaertn.): A unique source of food and medicine through tissue culture. Hamdard Med., **42**(1):37-42.

**Nair, M. K.; Varghese, C. and Swaminathan, R. (2015).** Cancer: Current scenario, intervention strategies and projections for 2015. NCMH Background Papers.

**Nakamura, Y.; Kawakami, M.; Yoshihiro, A.; Miyoshi, N.; Ohigashi, H.; Kawai, K. and Uchida, K. (2002).** Involvement of the mitochondrial death pathway in chemopreventive benzyl isothiocyanate-induced apoptosis. J. Biol. Chem., **277**(10):8492-8499.

**Nandave, M.; Ojha, S. K.; Joshi, S.; Kumari, S. and Arya, D. S. (2009).** *Moringa-oleifera* leaf extract prevents isoproterenol-induced myocardial damage in rats: Evidence for an antioxidant, antiperoxidative, and cardioprotective intervention. J. Med. Food., **12**(1):47-55.

**Paikra, B. K. and Gidwani, B. (2017).** Phytochemistry and pharmacology of *Moringa oleifera* Lam. J. Pharmacopuncture, **20**(3):194.

**Panda, S.; Kar, A.; Sharma, P. and Sharma, A. (2013).** Cardioprotective potential of N, α-L-rhamnopyranosylvincosamide, an indole alkaloid, isolated from the leaves of *Moringa oleifera* in isoproterenol-induced cardiotoxic rats: *In vivo* and *in vitro* studies. Bioorg. Med. Chem. Lett., **23**(4):959-962.

**Pareek, A.; Pant, M.; Gupta, M. M.; Kashania, P.; Ratan, Y.; Jain, V.; Pareek, A. and Chuturgoon, A. A. (2023).** *Moringa oleifera*: An updated comprehensive review of its pharmacological activities, ethnomedicinal, phytopharmaceutical formulation, clinical, phytochemical, and toxicological aspects. Int. J. Mol. Sci., **24**(3):2098.

**Prentki, M. and Nolan, C. J. (2006).** Islet β cell failure in type 2 diabetes. J. Clin. Invest., **116**(7):1802-1812.

**Sahakitpichan, P.; Mahidol, C.; Disadee, W.; Ruchirawat, S. andKanchanapoom, T. (2011).** Unusual glycosides of pyrrole alkaloid and 42 hydroxyphenylethanamide from leaves of *Moringa oleifera*. Phytochem., **72**(8):791-795.

**Sathyavathi, R.; Krishna, M. and Rao, D. N. (2011).** Biosynthesis of silver nanoparticles using *Moringa oleifera* leaf extract and its application to optical limiting. J. Nanosci. Nanotechnol., **11**(3):2031-2035.

**Sharifudin, S. A.; Fakurazi, S.; Hidayat, M. T.; Hairuszah, I.; Aris Mohd Moklas, M. and Arulselvan, P. (2013).** Therapeutic potential of *Moringa oleifera* extracts against acetaminophen-induced hepatotoxicity in rats. Pharm. Biol., **51**(3):279-288.

**Suresh, S.; Chhipa, A. S.; Gupta, M.; Lalotra, S.; Sisodia, S. S.; Baksi, R. and Nivsarkar, M. (2020).** Phytochemical analysis and pharmacological evaluation of methanolic leaf extract of *Moringa oleifera* Lam. in ovalbumin-induced allergic asthma. S. Afr. J. Bot., **130**:484-493.

**Tan, W. S.; Arulselvan, P.; Karthivashan, G. and Fakurazi, S. (2015).** *Moringa oleifera* flower extract suppresses the activation of inflammatory mediators in lipopolysaccharide stimulated RAW 264.7 macrophages *via* NF-κB pathway. Mediators Inflamm., **2015**(1):720171.

**Tiloke, C.; Phulukdaree, A. and Chuturgoon, A. A. (2013).** The antiproliferative effect of *Moringa oleifera* crude aqueous leaf extract on cancerous human alveolar epithelial cells.BMC Complement.Altern. Med., **13**:1-8.

**Upadhyay, P.; Yadav, M. K.; Mishra, S.; Sharma, P. and Purohit, S. (2015).** *Moringa oleifera*: A review of the medical evidence for its nutritional and pharmacological properties. Int. J. Res. Pharm. Sci., **5**(2):12-16.

**Varmani, S. G. and Garg, M. (2014).** Health benefits of *Moringa oleifera*: A miracle tree. Int. J. Food Nutr. Sci., **3**(3):111.

**Wang, F.; Bao, Y.; Zhang, C.; Zhan, L.; Khan, W.; Siddiqua, S. and Xiao, J. (2022).** Bioactive components and anti-diabetic properties of *Moringa oleifera* Lam. Crit. Rev. Food Sci. Nutr., **62**(14):3873-3897.

**Wang, F.; Yang, G.; Zhou, Y.; Song, H.; Xiong, L.; Wang, L. and Shen, X. (2022).** Pharmacokinetics of niazirin from *Moringa oleifera* Lam. in rats by UPLC MS/MS: Absolute bioavailability and dose proportionality. eFood, **3**(6):e39.

**Wang, J.; Du, Y.; Jiang, L.; Li, J.; Yu, B.; Ren, C.; Yan, T.; Jia, Y. and He, B. (2024).** LC-MS/MS-based chemical profiling of water extracts of *Moringa oleifera* leaves and pharmacokinetics of their major constituents in rat plasma. Food Chem., **23**:101585.

**Wright Jr, E.; Scism Bacon, J. L. and Glass, L. C. (2006).** Oxidative stress in type 2 diabetes: The role of fasting and postprandial glycaemia. Int. J. Clin. Pract, **60**(3):308-314.

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