INTERNATIONAL JOURNAL OF PHARMACEUTICAL SCIENCES
[ISSN: 0975-4725; CODEN(USA): IJPS00]
Journal Homepage: https://www.ijpsjournal.com

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Review Article

Phytochemicals And Health Benefits of Moringa Oleifera: A Comprehensive Review

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ARTICLE INFO

Published: 23 June 2025
Keywords:
Medicinal properties, nutritional value, clinical study, flavonoid
DOI:
10.5281/zenodo.15719540

ABSTRACT

Moringa oleifera in known as "miracle tree" which is rich of nutrients and medicinal value. In this review we looks at the plant's phytochemical substances and health benefits. Leaves, seeds, bark, roots, and pods are the different parts of the plant which contain useful phytochemical substances like flavonoids, alkaloids, tannins, phenolic acids, saponins, and vitamins. These natural compounds show many health effects. Many studies found that Moringa oleifera have antimicrobial, anti-inflammatory, antioxidant, anti-inflammatory, anti-inflammatory, and anticancer properties. This extracts is also beneficial for protect the liver, heart, and brain. They work by blocking harmful molecules, reducing inflammation, and affecting body signals. Water and alcohol-based extracts both demonstrate substantial efficacy. The results can vary based on which part of the plant is used and how it is extracted. Most research has been done in test tubes or on animals. These results are promising but not yet proven in humans. Few clinical trials have been done. More research is needed to know the best dose, safety, and long-term effects in people. Standardizing the extracts is also a challenge. Without this, it's hard to compare results or use Moringa in medicine. Still, Moringa oleifera is a strong candidate for use in health supplements and medicine. It offers a natural and low-cost source of many useful compounds. More human studies will help confirm its full potential.

INTRODUCTION

Moringa oleifera (*M. oleifera*), the widely cultivated in almost all tropical and subtropical regions worldwide. Moringa is originated in India, Afghanistan, Bangladesh, and Pakistan [1]. It is commonly known as the 'drumstick' or 'horseradish' tree, is prized for its production of thin, drumstick-resembling pods, a significant ingredient in the preparation of delicious dishes in Asia and Africa [2]. *M. oleifera* is belongs from Moringaceae family [3]. There are 13 species of moringa that are found. Those are *M. oleifera*, *M.*

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Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

rivae, M. ruspoliana, M. arborea, M. drouhardii, M. stenopetala, M. concanensis, M. hildebrandtii, M. pygmaea, M. borziana, M. longituba, M. ovalifolia and M. peregrina. Moringa is propuler by its diverse applications in areas like nutrition, biogas creation, and fertilizer etc. [4,5]. *Moringa oleifera* is rich in nutrients. Its leaves are high in beta-carotene, minerals, calcium, and potassium [6]. Its dried leaves, containing 70% oleic acid, are suitable for making moisturizing agents [7]. The tree's parts, including roots, bark, gum, leaves, pods, flowers, seeds, and seed oil, have been traditionally used in indigenous medicine to treat various ailments [8]. Its extensive medicinal properties and diverse pharmacological activities make it a powerful tool for health and medicine, potentially treating numerous conditions [9]. Native drug derived from a specific plant have been used to treat various types of diseases. Every part of the plant including its leaves, bark, sap, flowers, seed oil, and roots holds valuable healing properties, making it an important medicinal resource [10,11]. These healing properties help in treating conditions such as hypertension, anxiety, diarrhea, dysentery, and colitis [12,13]. To treat inflammation and related conditions leaves and pods of *Moringa oleifera* can be used [14]. In herbal medicine, to treat kidney stones [15], liver diseases [16], inflammation [17], ulcers [18], and provide relief from earaches and toothache [19] roots are used. The plant's gum is also used to treat fever and induce abortions [20,21]. The seeds have laxative potential. Those are used to treat prostate ailments, bladder, cancer [22] and arthritis [23].

The leaves also have potential for enhancing population health, aiding nursing mothers and undernourished babies. They increase estrogen synthesis, promoting milk secretion, and are instrumental in addressing malnutrition in children under three years of age. Moringa leaves are also valuable for insomnia and wound healing properties [24, 25]. For cleansing water, healthcare goods and cosmetics preparation like conditioners and moisturisers moringa is used [26, 27]. Secondary metabolites, including alkaloids, tannins, flavonoids, steroids, saponins, coumarins, quinones, and resins, contribute to its therapeutic properties [28].

Taxonomic classification [29]

Kingdom	Plantae
Super kingdom	Tracheobionta
Super division	Spermatophyta
Division	Magnoliophyta
Class	Magnoliopsida
Sub class	Dilleniidae
Order	Capparales
Family	Moringaceae
Genus	Moringa
Species	oleifera

Synonyms of *Moringa oleifera* [30]

Latin	*Moringa oleifera*
Sanskrit	Subhanjana
Hindi	Saguna, Sainjna
Gujarati	Suragavo
Tamil	Morigkai
Telugu	Mulaga, Munaga
Malayalam	Murinna, Sigru
Punjabi	Sainjna, Soanjna
Unani	Sahajan
Ayurvedic	Akshiva, Haritashaaka, Raktaka, Tikshnagandhaa
Arabian	Rawag
French	Moringe à graine ailée, Morungue
Spanish	Ángela, Ben, Moringa
Portuguese	Moringa, Moringueiro
Chinese	La ken
English	Drumstick tree, Horseradish tree, Ben tree

Morphological Characteristics:

Moringa oleifera is a medium sized tree which grows very first. Moringa plant reach up to 10-12 meters and always present in green and deciduous forms. It generally grows about 500m altitute in loamy and well-drained sandy soils. The tree is characterised by its soft, white wood and distinctive corky, gummy bark. Its leaves are trifoliate, measuring 30-75cm in length, with jointed branches and glandular nodes. The plant contain smooth and green leaflets that are finely hairy with unbroken edges. Its fragrant white flowers hang from branches in groups and are between 10-25 centimeters long. After flowering, the plant produces long, ribbed pods that hang down from the branches. The seeds are brown, triangular in shape, and covered by a semi-permeable hull [30,31,32].

Traditional Use of *Moringa oleifera*

In traditional medicine moringa is a plant that has many healing properties. Moringa leaves have a variety of theraputic effects which are antidiabetic, antibacterial, antiseptic, antiseptic, antipyretic and analgesic. The plant juice is used to treat hiccups but cooked leaves are useful for influenza and catarrhal treatment. For anti-inflammatory effects roots are popular and it used to treat colds and coughs. The bark is also known for its analgesic properties which provide medicinal value. Plant gum is soft and sweet and is known for its antibacterial properties. The leaves are contain high levels antioxidants. Moringa leaves contain antibacterial and anti-inflammatory properties. Bark of moringa is useful for antiulcer and low blood presure treatment. The pods have humectant and moisture-wicking properties, which help reduce humidity and repel insects. Decocted pods are very effective in managing diabetes. In Ayurvedic medicine the dried bark is useful for diarrhea, sugar in urine and fat related problems but the leaves, fruits and roots are used to treat diarrhea and joint pain [30, 33].

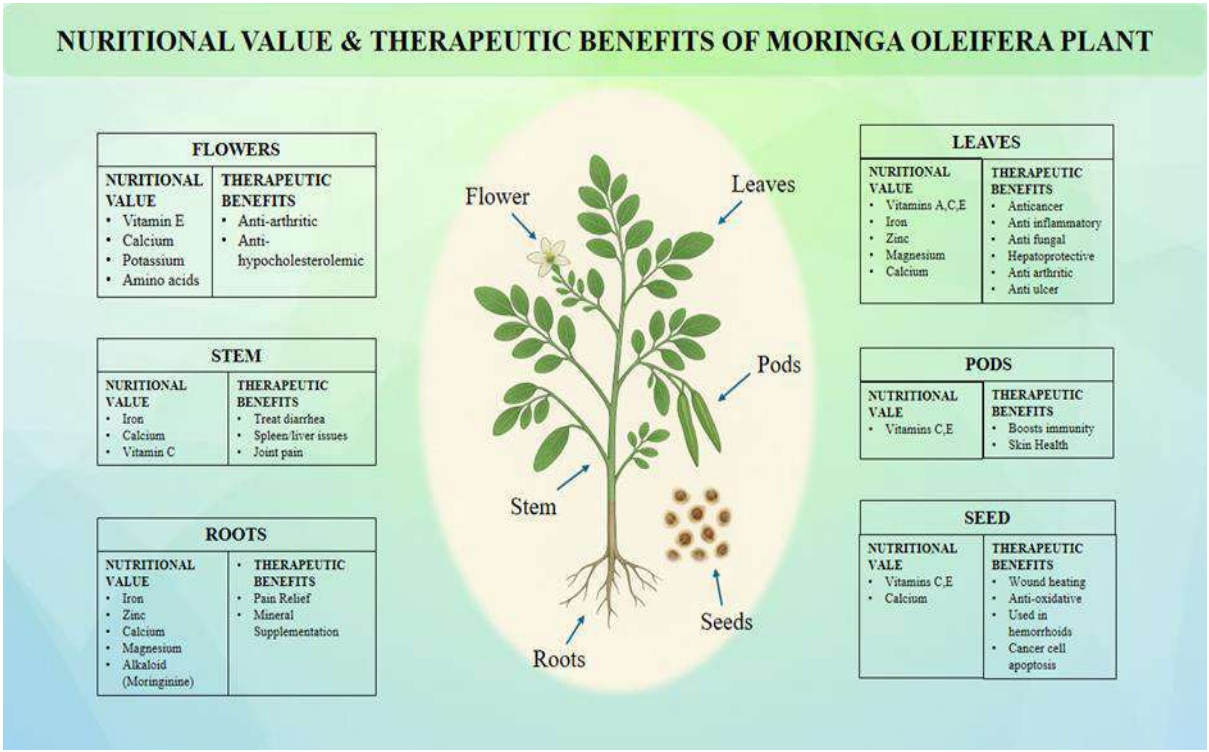

Figure 1: Nutritional and therapeutic value of *Moringa oleifera* [34, 35]

Table 1: The List of several phytoconstituents & pharmacological activity of *Moringa oleifera*

Parts of plants	Phytochemical constituents	Pharmacological activities	Reference
Leaves	Niazirin, Niazirinin, Niaziminin, Niazimicin A, Niazimicin B	antiepileptic, Antioxidant, Antihypertensive, antibacterial, antitumor activity & Acts against asthma,	[29,36]
Pods	Isothiocyanate, nitrites, β-Sitosterol	Act against inflammation & helmintics	[37]
Flower	Quercetin, Isoquercitin, Kaempherol, Kaempferitrin, Ascorbic acid	Antioxidant, Hepatoprotective, antimicrobial, anti-inflammatory activity	[8,38]
Seeds	Niazirin, Niazimicin, Isothiocyanates, Glucosinolates, Oleic acid, Linoleic acid, β-Sitosterol	Antimicrobial, Anticancer, Antidiabetic, Antioxidant, Cardioprotective	[8,39]
Root	Moringine, moringinine, Glycosides, Steroids	Hepatoprotective, Cardioprotective, Anti-inflammatory,	[8]
Barks	Alkaloids, Tannins, Saponins, Flavonoids	Antimicrobial, Anti-inflammatory, Wound healing	[40]
Steam	Vanillin, β-sitosterone	Anticancer, Antihypertensive, Anti-inflammatory	[8]

Pharmacological properties of *Moringa oleifera*:

Antibacterial and Antifungal Activity

Moringa leaves contain verious types of compounds. Antibacterial, antifungal, antiviral and antiparasitic properties are present in those compounds. However, few reports suggest they contain chemical metabolites. Pterygospermin, moringine and benzyl isothiocyanate are obtained from crude leaf extract. Which are responsible for antibacterial activity. Apigenin is a naturally obtain flavonoid and it is also a potential green chemical exhibits broad-spectrum antibacterial activity against both Gram-positive and Gram-negative bacteria, including *Bacillus subtilis*, *Escherichia coli*, and *Pseudomonas aeruginosa*. These substances may be used to fight antibiotic resistance [41]. A component in the root extract, 4-L-rhamnosyloxybenzyl isothiocyanate, gives moringa blossom antibacterial and antifungal properties. These effects are attributed to deoxy-niazimicine's glycine. This compound has been separated from the chloroform fraction after ethanol extraction of the root and bark. A number of study show stem juice of moringa shows antibacterial activity against *Staphylococcus aureus* but its bark extract has antifungal activity [34]. A study found that ethanolic extracts from the root and bark of *Moringa oleifera* have significant antifungal effects. Those extract significantly inhibit fungi like *Aspergillus niger*, *Neurospora crassa*, *Rhizopus stolonifer* and *Microsporum gypseum* [42]. These extracts have also shown the ability to inhibit the growth of a parasite (*Leishmania donovani*) that causes leishmaniasis [43]. Several studies have indicated that *Moringa oleifera* seed extracts may serve as an effective natural option for water purification. These extracts have been shown to inhibit bacterial growth in both agar and nutrient media [44].

Anti-inflammatory activity

The Moringa plant also have strong anti-inflammatory activity. Researchers found that the root extract have significent anti-inflammatory effects against carrageenan induced rat paw oedema. Study also found that *Moringa oleifera* seeds contain n-butanol which ablr to show anti-inflammatory activity against ovalbumin induced airway inflammation [34]. *M. oleifera* leaves, pods, flowers and roots have a significant anti-inflammatory effect. Research showes that 4-[2-o-Acetyl-alpha-l-rhamnosyloxy) benzyl] thiocyanate, a chemical discovered in *Moringa oleifera*, has nitric oxide inhibitory action, making it effective in Raw264.7 cell lines. *Moringa oleifera* roots contain boiactive compound like aurnatimide acetate and 1,3-dibenzylureahave. That are significantly inhibit TNF-α production [41]. In a study researchers evaluated ethanolic extract of Moringa pods for anti-inflammatory activity against pro-inflammatory mediators. Which is generated by lipopolysaccharide induced murine macrophages. The Moringa extract can significantly inhibit mRNA transcription. Depend on dose it also inhibit the concentrations of IL-6, TNF-α, iNOS and cyclooxygenease-2. This inhibition is somehow mediated by the inhibiting kappa B protein phosphorylation [45]. Bioactive compounds like alkaloids, flavonoids, tannins, phenols, vanillin, carotenoids β-sitosterol and moringin are present in moringa. These compound help to supress inflammation [21].

Antioxidant Activity

Researchesr recognized that *Moringa oleifera* also significant and valuable source of antioxidant. A notable antioxidant properties exhibited by aqueous extracts of *Moringa oleifera* leaves, fruits and seeds. Researchers found that quercetin and kaempferol is suitable for radical scavenging properties than palm oil. Those phenolic compounds are present in the seed extract of *Moringa oleifera*. For that moringa seed have greater antioxidant activity [46]. Moringa leaf extract also has good antioxidant properties. Now the naturally obtain antioxidants have a high demand for wound healing by lowering oxidative stress and stimulating tissue regeneration. Isothiocyanates, glucosinolates and thiocarbamates are present in moringa extract which is also responsible for significant antioxidant activity [47]. Researchers compared the the antioxidant properties of *Moringa oleifera* leaf extracts with standard in the in vitro models. In this experiment extracts showed significant scavenging effects on DPPH free radical, superoxide, nitric oxide radical and lipid peroxidation. According to studies, Moringa oleifera leaf extract has a significant free radical scavenging action that is similar to standard reference antioxidants [48].

Anticancer activity

Various studies have proved that *Moringa oleifera* has significant anticancer effects. Thiocarbamate and niazimicin present in moringa leaves which are responsible for anticancer activity [49,50]. Researchers examine the cytotoxicity of moringa leaf and seed extract against several cancer cell lines. All the time leaves and seed extracts were proved their anticancer capabilities. Studies show that various parts of the *Moringa oleifera* like fruits, leaves, flowers and stems have effects against cancer cells. Isothiocyanates and thiocarbamates have capability to inhibit tumour cell proliferation. Study also found that moringa isothiocyanates (MIC-1) help to suppress cancer development with minimal impact on normal cells. Furthermore, extraction of moringa leaves and fruits, particularly those infused with alcohol or hydro-methane, have showed promise in suppressing tumor growth [1,34]. Due to natural composition and ability to inhibit cancer cell

growth *Moringa oleifera* can be trustable and safe anticancer agent. Studies have shown moringa can treat various type of cancer. Blood, liver and bone marrow cancer can be treated by *Moringa oleifera* [33]. Studies show that Moringa leaf, bark and seed extracts have significant anti-cancer effects on breast and colorectal cancer cell lines in humans. The aqueous extract of Moringa leaves has been shown to reduce cancer growth and progression in human lung cells by causing apoptosis, DNA breakage, and increasing oxidative stress. This indicates that Moringa leaves may have the ability to reduce cancer cell multiplication and invasion [51].

Antidiabetic activity

Diabetes is a chronic disease and this condition occurs when the glucose level increase. There are generally two types of diabetes and the main function of treatment is to control the sugar level. Various study prove that moringa can control the blood sugar levels. Moringa leaf extract has been found to have potential hypoglycemic effects in alloxan-induced diabetic rats by reducing gluconeogenesis and regenerating damaged hepatocytes and pancreatic β-cells [51]. The study identified five phytochemicals, including a-phenolic steroid, sitogluside, hemlock tannin, 2-phenylchromenylium, and anthraquinone, which effectively reduced blood glucose levels in the active pocket of targeted proteins. *M. oleifera* extracts showed higher anthraquinone concentration, indicating higher antidiabetic activity than standard acarbose. Highest α-amylase inhibitory activity was shown by hexane and methanol extracts with IC50 values [47]. In another study the leaf extract of *Moringa oleifera* has been evaluated for antidiabetic activity in type 2 diabetes patients. The patient group was selected by age between 40 to 58 years. The experiment was running for three months. They observed moringa significantly reduced the blood glucose levels from 210 mg/dl to 150 mg/dl. The glycohemoglobin level also reduced from 7.81% to 7.4% after 90 days of dosing[51,52]. Another study found thar aqueous extracts of moringa plant have anti-diabetic effects in rats by controlling blood glucose levels, proteins, sugar and hemoglobin. In a research moringa leaves are compared with the standard drug glibenclamide. They found that the leaves of the plant can lower glucose levels within three hours of consumption. That is similar to the standard drug. *Moringa oleifera* seeds have been studied for their antihyperglycemic properties, particularly due to the presence of insulin-like proteins with antigenic epitopes [41].

Hepatoprotective activity

Studies prove that *Moringa oleifera* leaf aqueous extracts contain flavonoids, phenolic acids and carotenoids. Those compound shows strong hepatoprotective effects [53]. These compounds act together to provide therapeutic effects and potential health advantages. *Moringa oleifera* should be consumed on a regular basis [54]. However, excessive consumption of Moringa powder may lead to iron accumulation which can cause gastrointestinal discomfort and increase the risk of hemochromatosis. Study show that daily consumption of up to 70 grams can avoid excessive nutrient accumulation [55]. Another experiment was held to evaluate the hepatoprotective activity against liver damage induced by antitubercular drugs on rat. Researchers observe that moringa leaves extract have significantly lowering activity of aspartate aminotransferase, alkaline phosphatase, alanine aminotransferase in serum and bilirubin in the liver [56]. A different study was performed to observe the acetaminophen induced hepatotoxicity on mice. Here moringa leaf extract also shows

significant activity by lowering serum AST, and gamma-glutamyl transpeptidase (γ-GT) levels. while enhancing antioxidant enzyme activity in the liver [57]. Research proven that moringa leaf extracts can protect liver damage [56] and help reduce liver fibrosis [58]. The various flavonoids present in moringa. Quercetin is one of them which found in moringa flowers is responsible for the hepatoprotective action [23]. Study also found the seeds extract also able for treating carbon tetrachloride induced liver fibrosis. The extract show this action by decrease in blood aminotransferase activity and globulin levels [1]. This plant extract's alkaloid, quercetin, kaempferol, flavonoids, ascorbic acid and benzyl glucosinolates were shown to have significant effects on liver damage when consumed on a daily basis for 21 days [21].

Cardioprotective activity

Various studies found that *Moringa oleifera* has hypolipidemic effects. Studies also prove that daily consumption of Moringa leaf extracts can significantly reduce cholesterol levels and improve heart health. A study was perform on hypolipidemic activity in rabbits. Rabbits ware fed a high-cholesterol diet for three months. In result daily consumption of Moringa leaf extract reduces 50% cholesterol levels and 86.5% in plaque development in the internal carotid arteries compared to the control group. The result was similar to the simvastatin treated group [59]. An another research on rat prove that daily consumption of Moringa leaves methanolic extracts at doses of 150, 300 or 600 mg/kg of body weight for 30 days helped reduce serum lipids in a high-fat diet. 300 or 600 mg/kg of body weight dose of moringa leaf can significantly reduce total cholesterol, triglycerides, LDL, VLDL and the atherogenic index but it can increasing HDL [60]. Study also said that Moringa oleifera has cardioprotective activity due to the presence of polyphenols. Polyphenols perform cardio protection by inhibiting hepatic cholesterol and lipoprotein metabolism. It also reduces the inflammatory response [61]. In a study researchers used potassium bromate to cause cardiac tissue damage in rats. Moringa extracts was given to assess their detoxifying efficacy. Potassium bromate is a cardio-toxin that promotes lipid peroxidation and decreases cardiac antioxidant activity. Elevated cardiac biomarker enzymes (AST, ALT, ALP) and other components on cardiac tissues showed cardiac dysfunction in rats induced by potassium bromate. Results show that the *Moringa oleifera* extract protects against potassium bromate-induced cardiac oxidative damage in rats, reducing antioxidant loss and helping restore normal heart function [62].

Wound healing activity

Moringa oleifera leaves have shown promising wound healing potential by significantly increasing the proliferation and migration of diabetic human dermal fibroblast cells [47]. The bioactive compound hydroxyproline, extracted from *Moringa oleifera* seeds, dried pulp and leaves has been shown to reduce scar area and skin breaking strength in dead rat models [63] . Others studies found that ethyl acetate and aqueous extracts of *Moringa oleifera* leaves have significant wound healing activity in models of incision and excision injuries. If it administered at a dose of 300 mg/kg body weight [1]. In a research on diabetic animal models found that moringa leaf extracts have significant wound healing potential. This extract work by reducing inflammatory mediators and enhancing the production of vascular endothelial growth factor in damaged tissues [21]. *Moringa oleifera* aqueous extract also have significant activity on healing diabetic foot ulcers. The extract reduces several inflammatory

markers to show the effect [64]. *Moringa oleifera* leaf extracts have been shown to promote wound healing in diabetic mice. The extract can enhancing tissue regeneration and increasing the levels of proteins. That involved in the formation of tubular epithelial structures within the damaged tissue [64, 65].

CONCLUSION

Moringa oleifera is one of the popular plant which has a long history in traditional medicine. Now a days it becoming most important in current pharmacology. This plant generally found in South Asia region. But now it grown in tropical and subtropical areas [66]. For human medication various parts of the plant are used. In this review traditional, therapeutic and pharmacological use of the plant is explained. *Moringa oleifera* extract contain alkaloid, flavonoid, tannins and isothiocyanate class compounds [67]. Those compounds are found from leaf, stem bark and flowers which are show significant antibacterial and antifungal activity. In the antinflametory activity plant also exhibited good inhibition activity. Mainly the alcoholic extract of the moringa shows a significant effect on various cell lines. Among them Raw264.7 cell lines are more significant [68]. Moringa Seed and leaf extract show significant antioxidant activity. Moringa seeds contain phenolic compounds. For that seed extract show most significant effect on antioxidant activity. Both aqueous and alcoholic extracts of Moringa have potent anticancer activity on various cell lines. Moringa can be an alternative option for treating various types of cancer [69]. Among them moringa extract show very good inhibitory activity on lung, breast and colorectal cancer. Some in-vivo and in-vitro antidiabetic experiments proven that moringa extract has good inhibitory activity in diabetic conditions [70]. Moringa is also considered for hepatoprotective, cardioprotective and Wound healing activity. It also help to regulate cholesterol levels and inhibits plaque development. Main challenges to develop a particular medicine from the extract and maintain stability, dose and patient seafty. Complete mechanism is still needed for therapeutic potential.

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HOW TO CITE: Aditi Anand, Faizi Alam, Subham Roy*, Chayanika Goswami, Phytochemicals and Health Benefits of Moringa Oleifera: A Comprehensive Review, Int. J. of Pharm. Sci., 2025, Vol 3, Issue 6, 3525-3537. https://doi.org/10.5281/zenodo.15719540