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Review on the Pharmacological and Therapeutic Potential of Nelumbo nucifera (Lotus Plant)

Akshay R. Bitle[1], Sajiya A. Tamboli[2], Akanksha S. Chavan[3], Ratika D.Shelar[4]
[1,2,3]Students, JBVP`S Vidya Niketan Collage of Pharmacy, Lakhewadi
[4]Assistant Professor, JBVP`S Vidya Niketan Collage of Pharmacy, Lakhewadi

Abstract: *Nelumbo nucifera, commonly known as lotus or sacred lotus, is an aquatic perennial plant revered for its immense medicinal, nutritional, and spiritual significance. Belonging to the family Nelumbonaceae, it has been used traditionally across Asia in systems of medicine such as Ayurveda, Traditional Chinese Medicine, and others. This review aims to present a comprehensive analysis of the phytochemical constituents and pharmacological activities of various parts of N. nucifera including seeds, leaves, rhizomes, flowers, and roots. The plant demonstrates wide-ranging pharmacological activities such as antioxidant, anticancer, antiinflammatory, hepatoprotective, hypoglycemic, neuropharmacological, anti-aging, and immunomodulatory effects, among others. The presence of multiple bioactive compounds including alkaloids, flavonoids, polyphenols, and glycosides makes this plant an important candidate for pharmaceutical and therapeutic applications[1-4].*

Keywords: Sacred Lotus (Nelumbo nucifera): The primary subject of the review; an aquatic perennial plant with deep spiritual and nutritional roots

I. INTRODUCTION

Nelumbo nucifera (sacred lotus) is a well-known aquatic plant with deep roots in traditional medicine, spirituality, and nutrition, particularly in Asia. It is widely cultivated in India, China, Japan, and Southeast Asia, where it is valued not only for its symbolic purity but also for its therapeutic benefits. Used in systems like Ayurveda, Unani, and Traditional Chinese Medicine, every part of the plant—leaves, seeds, flowers, rhizomes—serves a medicinal purpose[1,5].

Modern research has validated many traditional claims, showing that N. nucifera possesses a broad spectrum of pharmacological activities including antioxidant, antiinflammatory, anticancer, hepatoprotective, hypoglycemic, neuroprotective, and antimicrobial effects. These actions are largely attributed to its rich content of alkaloids, flavonoids, polyphenols, and essential nutrients. As a result, it is now considered a promising natural source for drug development and functional foods[2,3,6,7].

Taxonomic Classification :

Kingdom: Plantae
Division: Magnoliophyta
Class: Magnoliopsida
Order: Proteales
Family: Nelumbonaceae
Genus: Nelumbo
Species: Nelumbo nucifera Gaertn.

The plant has floating leaves and emergent flowers. Its rhizomes are thick and tuberous, and the seeds are enclosed in a spongy receptacle. Flowers are large, aromatic, and available in pink, white, or red hues. It thrives in muddy aquatic environments and is distributed widely in Asia and Oceania[8].

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II. PHYSICAL CHARACTERISTICS AND DESCRIPTION

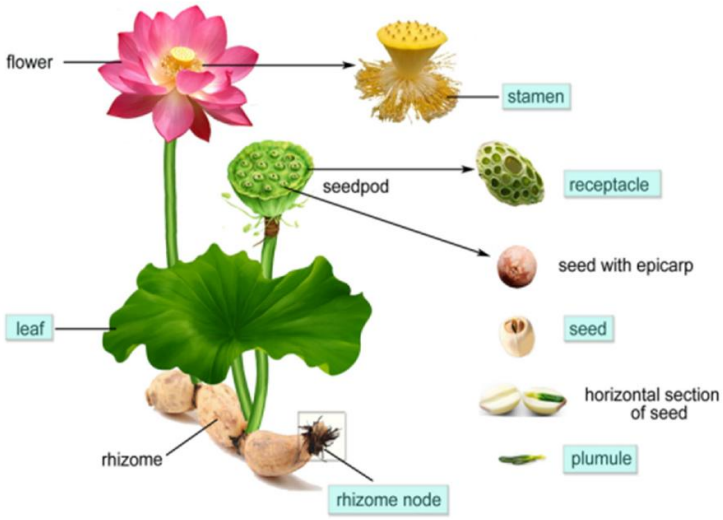
Nelumbo nucifera is a perennial aquatic plant rooted in the muddy bottoms of freshwater bodies like ponds and lakes. It has a **rhizomatous stem** that creeps horizontally beneath the water, producing **long petioles** that support large, circular leaves (up to 60 cm in diameter). These leaves can be either floating or held above the water surface and have a waxy coating that repels water[1,8].

The plant produces **solitary, showy flowers** in shades of pink, white, or red, which are **fragrant and hermaphroditic**, blooming above the water. The flowers are about 10–25 cm wide and contain both male (stamens) and female (carpels) parts. After pollination, the plant develops **cone-shaped seed pods** with embedded black seeds, which are highly resilient and viable for many years.

Its **rhizomes (underground stems)** are thick, tuberous, and rich in starch—often consumed as a vegetable in Asian cuisine. Inside, the rhizome contains **large air canals** that help the plant maintain buoyancy and gas exchange under water. The entire plant structure is well adapted to aquatic environments, combining **beauty, resilience, and functionality**[9,10].

III. CHEMICAL CONSTITUENT

Nelumbo nucifera contains a wide range of bioactive compounds that vary across different parts of the plant. These constituents are responsible for the plant's diverse pharmacological activities.



Seeds [3,11]
Nutrients: Proteins, starch, lipids, and dietary fiber
Alkaloids: Neferine, isoliensinine, liensinine
Minerals: Calcium, potassium, magnesium, phosphorus, iron, zinc
Polyphenols: Catechins, gallic acid derivatives
Others: Tannins, flavonoids, vitamins (notably Bcomplex)
Leaves [6,12]
Major Alkaloids: Nuciferine, roemerine, anonaine
Flavonoids: Quercetin, kaempferol, isoquercitrin
Phenolic Compounds: Chlorogenic acid, gallic acid
Volatile Oils: Provide mild aromatic and therapeutic effects
Flowers [14]
Flavonoids: Kaempferol, isorhamnetin, myricetin
Glycosides: Nelumboroside A and B

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Others: Arbutin, myo-inositol, saponins

Rhizomes [9]

Carbohydrates: Starch (about 30–40%)

Triterpenoids: Betulinic acid

Vitamins and Minerals: Especially Vitamin C, potassium, and dietary fiber

Polysaccharides and Mucilage: Support digestive and prebiotic functions

Embryos (Seed Germs) [4]

Alkaloids: Neferine (central nervous system-active compound)

Flavonoids: Promote neuroprotective and anti-stress actions.

Summary :

These chemical constituents contribute to Nelumbo nucifera's pharmacological actions such as antioxidant, hepatoprotective, anti-inflammatory, anticancer, neuroprotective, and hypoglycemic effects. The presence of alkaloids, flavonoids, phenolics, glycosides, and essential nutrients makes this plant a powerful candidate for herbal medicine and drug development[2,6,7].

IV. CULTIVATION

Nelumbo nucifera thrives in shallow freshwater wetlands. The ideal soil is loamy and rich in organic matter. Cultivation requires consistent water depth of around 20–30 cm and warm temperatures (25–30°C)[8].The plant is propagated through both seeds and rhizomes.

Seed Propagation: Seeds are scarified to break dormancy and soaked in warm water. Germination occurs within a few days. Seedlings are transplanted once roots and shoots develop[9].

Rhizome Division: This method ensures true-to-type propagation. Healthy rhizomes with apical buds are planted 15 cm deep in soil and spaced 30–40 cm apart. Lotus plants require full sunlight and regular weeding[1].

Fertilization with nitrogen and phosphorus enhances growth.Harvesting is done at different times based on the intended use (e.g., rhizomes for food, seeds for medicine, flowers for decorative and therapeutic purposes)[8].

V. USED FOR TRADITIONAL MEDICINES :

In traditional medicine, every part of the lotus plant is used to treat a variety of ailments:

Seeds: Used as astringents and tonics for the kidneys and spleen. Treat insomnia, palpitations, and premature ejaculation[1,5].

Leaves: Effective against diarrhea, bleeding disorders, and obesity. Used as a cooling agent for sunstroke and fever[13].

Flowers: Help control bleeding, calm the mind, and are used in treatments for premature ejaculation and cardiovascular ailments[1].

Rhizomes: Used to treat inflammation, digestive disorders, and as a diuretic. Their cooling properties help manage fever and heat-related illnesses[6,14].

Embryos (germ of seeds): Believed to nourish the heart and calm the spirit. Used for hypertension and nervous disorders[5].

In Chinese medicine, lotus is classified as sweet and astringent, neutral in temperature, and mainly targets the heart, kidney, and spleen meridians[10].

VI. PHARMACOLOGICAL ACTIVITIES

Nelumbo nucifera exhibits the following pharmacological activities:

Antioxidant: Seed extracts reduce oxidative stress by scavenging free radicals and enhancing enzymes like SOD and catalase. Shown to be effective in both in vitro and in vivo models[2,3].

Anticancer: Alkaloids such as isoliensinine and neferine induce apoptosis in breast, prostate, and melanoma cancer cells. Mechanisms involve ROS generation and MAPK/JNK pathway activation[2].

Anti-inflammatory: Compounds like betulinic acid suppress pro-inflammatory cytokines (IL-6, TNF-α). Effective in models of edema and chronic inflammatory conditions[4,6].

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Hepatoprotective: Seed extracts prevent hepatic damage from toxins like carbon tetrachloride by restoring enzyme levels and reducing lipid peroxidation[7].

Hypoglycemic/Antidiabetic: Rhizome and leaf extracts lower blood glucose in diabetic rats. Enhance insulin sensitivity and glucose metabolism[11].

• **Neuropharmacological/Psychopharmacological**: Neferine shows antidepressant-like effects via serotonin receptor modulation. Improves sleep, reduces anxiety, and acts as a CNS depressant [5,12].

Antibacterial/Antiviral: Effective against pathogens like E. coli, Salmonella, HSV-1. Lotus polyphenols disrupt microbial membranes [15].

Anti-aging: Lotus extracts protect against collagen degradation, reduce wrinkles, and improve skin hydration and elasticity[13].

Anti-obesity: Leaf extracts reduce fat accumulation by modulating lipid metabolism and increasing lipolysis[16],

Immunomodulatory: Boosts immune function by stimulating NK, T, and B cells. Enhances cytokine secretion[17].

Other Effects:

Diuretic: Rhizome extracts promote sodium and chloride excretion[1].

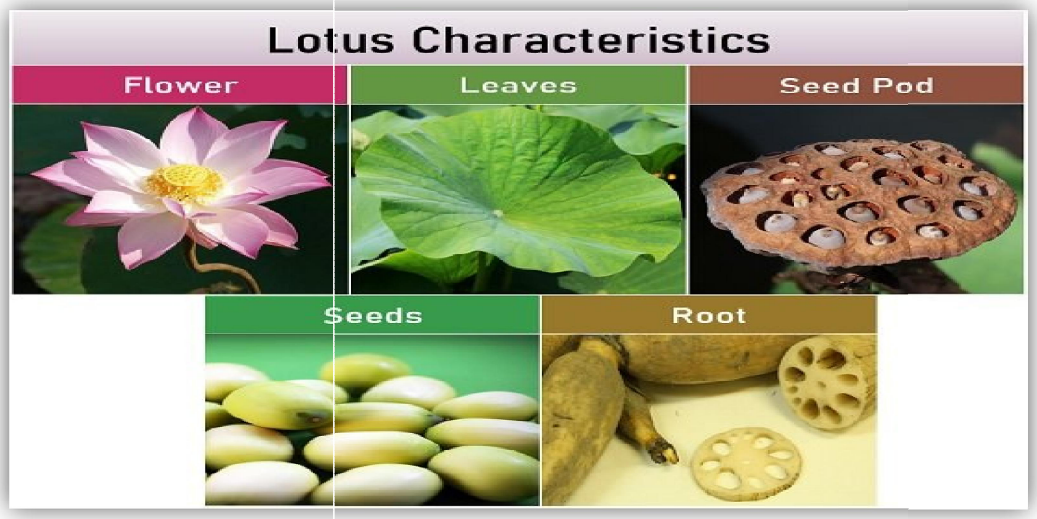
Analgesic: Inhibits prostaglandin pathways to relieve pain[3].

Anti-ischemic: Improves blood flow and cardiac output in ischemic models[6].

Antiplatelet: Flower extracts inhibit platelet aggregation, preventing thrombosis[14].

Gastrointestinal: Enhances probiotic growth, improves digestion, and regulatesmotility.

VII. MORPHOLOGICAL CHARACTERISTICS :



General Habit & Structure

Nelumbo nucifera is a rhizomatous perennial aquatic herb, rooted in muddy freshwater bottoms. Its long petioles, sometimes up to 2 meters, support large leaves that either float or rise above the water surface.

The rhizomes are branched, horizontal stems with swollen storage tubers and nodal roots—critical for anchorage, nutrient storage, and vegetative growth[1].

Leaves

The leaves are peltate (i.e., stalk attached at the centre), orbicular, and can reach up to 80 cm in diameter.

Surface is covered with papillose epicuticular waxes, giving the leaves their superhydrophobic, selfcleaning property ("lotus effect")—droplets roll off effortlessly[20].

Veination is radiating/palmate, with long petioles often armed with fine prickles.

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Flowers

Solitary, fragrant, and remarkably showy, lotus flowers range from 10–35 cm in diameter, with colors from white to pink.

Petals and stamens are numerous; certain cultivated varieties can have thousands of petals (e.g., "thousand-petals lotus").

Flowers are held well above water on robust stalks and exhibit thermogenic properties, maintaining ~30°C in cooler ambient conditions to attract pollinators[14].

Reproductive Structures (Fruit & Seeds)

The fruiting structure is an obconical receptacle housing multiple small, hard achenes—olive- to seedlike fruits embedded in a flattened, spongy platform.

Seeds are oval to ellipsoid, with extremely hard coats; they are known to remain viable—germinating even after centuries[10].

Internal Anatomy & Microscopic Traits

Rhizomes contain large central air canals (4–6 central with many peripheral), separated by diaphragms to maintain structure while ensuring gas diffusion—an adaptation to aquatic environments.

Leaves' surface microstructure includes hierarchical waxy tubules and papillae (200–400 nm nanostructures plus 5–10 μm microstructures) which enhance water repellency and cleanliness [20].

VIII. PHYTOCHEMICAL INVESTIGATION

1. Overview of Phytochemical Constituents Extensive studies reveal that Nelumbo nucifera harbors a rich variety of bioactive compounds—including alkaloids, flavonoids, glycosides, triterpenoids, and vitamins—across its major organs (seeds, rhizomes, leaves, flowers) These constituents underlie its broad therapeutic potential[3,6,7]**.**

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2. Tissue-Specific Phytochemical Distribution Leaves

Dominant aporphine alkaloids such as nuciferine exhibit psychoactive and anti-inflammatory actions [21].

Flavonoids like miquelianin, coclaurine, and norcoclaurine also occur prominently.

I. Flower Buds (Petals, Stamen, Receptacle)

Ten key alkaloids quantified include aporphine alkaloids (e.g., nuciferine, nornuciferine, pronuciferine) and benzylisoquinoline alkaloids (e.g., armepavine, coclaurine)[12].

These compounds correlate directly with skin-related pharmacological activities like melanogenesis inhibition.

II. Seeds and Embryos

• Discovery of four new flavone C-glycosides (nelumbosides A–D) and additional known flavonoids and alkaloids via NMR and MS techniques Some exhibited strong antioxidant activity (SC_{50} ≈ 12–26 μM) [23].

III. Seed Plumules vs. Leaves

• Using UPLC-QTOF-HRMS and MALDI–MS imaging, researchers identified 46 benzylisoquinoline alkaloids varying by tissue[24].

Glycosylated monobenzylisoquinolines were enriched in seed plumules.

Aporphine alkaloids were more prevalent in leaves;bisbenzylisoquinolines concentrated in plumules.

IV. Phenolic Acids & Flavonoids Across Organs

• Quantitative profiling showed:

Gallic acid in petals, leaves, and stalks (≈ 49– 278 mg/100 g DW).

Ferulic acid in embryos (≈ 25 mg/100 g DW); p-coumaric acid in embryos and stamens[25].

Among flavonoids:

Naringenin richest in embryos, petals, stamens (≈ 1,064–2,242 mg/100 g DW).

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Quercetin varied widely across tissues (≈ 36–459 mg/100 g DW); isorhamnetin, kaempferol, luteolin, myricetin, and anthocyanidins (cyanidin, delphinidin) also showed distinct patterns.

IX. CONCLUSION

Nelumbo nucifera is a pharmacologically significant plant with extensive traditional and modern applications. The wide range of bioactive compounds found in various parts of the plant underscore its potential in treating chronic diseases and promoting wellness. Continued research and clinical validation could further enhance its utility in modern medicine[1,6,21].

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