International Journal of Biomedical and Advance Research
ISSN: 2229-3809 (Online); 2455-0558 (Print)
Journal DOI: https://doi.org/10.7439/ijbar
CODEN: IJBABN

Review Article

A review of the important pharmacological activities of *Nelumbo nucifera*: A prodigious rhizome

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Abstract

Objectives: *Nelumbo nucifera* also known as Lotus, an aquatic perennial crop, belongs to the family of Nelumbonaceae. It is cultivated throughout the world as an important nutritious vegetable. The objective of this review article is to discuss therapeutic and pharmacological benefits of various bioactive compounds isolated from different parts of this miraculous plant.

Methodology: In this review article we have discussed the current pharmaceutical, phytochemical and pharmacological information about this well-known plant species by gathering the information from different research articles.

Discussion: In this study we have focused on the rhizome of *Nelumbo nucifera* because it possesses high economic value due to the abundance of bioactive compounds that have a miraculous health promoting effect on the human body. These bioactive compounds include: alkaloids, lipids, xanthophylls, nuciferine, phospholipids, carotenes flavonoids, aporphines etc. However, the rhizome of *Nelumbo nucifera* is most commonly used in the preparation of traditional food item most commonly in China and Asian countries. Mainly *Nelumbo nucifera* is cultivated in Japan and China, however, it is inhabitant of India, China and Japan. It is most commonly found in ponds as it is an aquatic herb. Due to its sweet fragrance of the flower it is considered as the national flower of India. *Nelumbo nucifera* is used in the treatment of leprosy, cancer, tissue inflammation, skin diseases and most prominently as an antidote of poison.

Conclusion: This review highlights several pharmacological and phytochemical studies that have demonstrated the therapeutic potential of *Nelumbo nucifera*. This needs to be explored further through clinical studies on human volunteers to provide evidence-based therapeutics.

Keywords: *Nelumbo nucifera*, aquatic herb, leprosy, cancer, nerve exhaustion.

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***Article History:**
Received: 25/12/2018
Revised: 08/01/2019
Accepted: 10/01/2019
DOI: https://doi.org/10.7439/ijbar.v10i01.5007

QR Code

How to cite: Ahmed, H., Hakani, G., Aslam, M., & Khatian, N. A review of the important pharmacological activities of Nelumbo nucifera: A prodigious rhizome. *International Journal of Biomedical and Advance Research* 2019; 10(01): e5007. Doi: 10.7439/ijbar.v10i01.5007 Available from: https://ssjournals.com/index.php/ijbar/article/view/5007

1. Introduction

Nelumbo nucifera also known as Lotus, an aquatic perennial crop, belong to the family of Nelumbonaceae. It is cultivated throughout the world as an important nutritious vegetable. However, the rhizome of *Nelumbo nucifera* possesses high economic value due to the abundance of compounds that has a miraculous health promoting effect on the human body. These compounds include: alkaloids, lipids, xanthophylls, nuciferine, phospholipids, carotenes flavonoids, apophines etc. The rhizome of *Nelumbo nucifera* is most commonly used in the preparation of traditional food item most commonly in China and Asian countries [1]. *Nelumbo nucifera* is known by different names in many languages such as:

Language : Commonly known name of lotus
Tamil : Ambal, Thamarai, Padma, Pankaja, Kamala
German : Indischelotosblume
Gujrat : Suriyakamal Malayalam – Tamara
Bengal : Padma
French : Nelumbo
Sanskrit : Ambuja
Hindi : Kanwal, Kamal
Persian : Nilufer [2, 3].

Whereas, in China it is known as Chinese water lily. The two species of *Nelumbo* are most commonly consumed throughout the world, i.e. *N. lutea* Wild and *N. nucifera* [4].

Mainly N. *nucifera* is cultivated in Japan and China, however, it is inhabitant of India, China and Japan.

It is most commonly found in ponds as it is an aquatic herb. Due to its sweet fragrance of flower it is considered as the national flower of India [5].

2. Historical background

Nelumbo nucifera is considered as sacrosanct and a symbol of purity because of its flower. In ancient times, it has been grown for 5000-7000 years in Far East and was known to be found in aquatic habitats 135 years ago. Moreover, it has been planted for 3000 years as a food, medicine and for a divine purpose. There are several spiritual believes of different sects. Lotus had grown by Buddhist friar at a lake in China because they consider lotus as tranquility and peace. However, lotus carries many names in Sanskrit with different spiritual beliefs, such as:

Padma : It rushes out with clear petals and gives off a perfect fragrance on the surface of water.
Kamal : Kamal signifies lotus as a highly spirited flower on the water.
Pankaja : It is pristine and develops in sludge [6].

3. Taxonomic classification of *Nelumbo nucifera*

The taxonomical classification of *Nelumbo nucifera* is as follows:

Family : Nelumbonaceae
Class : Magnoliopsida
Sub Class : Magnolidae
Super Order : Protaenae
Genus : *Nelumbo Adans*
Specie : *Nelumbo nucifera* Gaen [7].
Kingdom : Plantae

4. Constituents found in different Parts of *Nelumbo nucifera*

4.1 Seeds

The seeds of N. *nucifera* contains high amount of fat, amino acids, protein, asparagine, starch, unsaturated fatty acids, tannin and minerals. From the seedpod of lotus procyanidin was isolated.

A variety of minerals have also been found in the seed of *Nelumbo nucifera* such as: Sodium, Potassium, Chromium, Calcium, Magnesium, Zinc, Iron, Manganese, Copper.

Other nutritional elements include moisture, fat, protein and ash. It contains a crude form of carbohydrate and fibre. Secondary metabolites include alkaloids like liensinine, isoliensinine, roemerine, neferine, nuciferine, lotusine, dauricine, pronuciferine and armepavine [4].

4.2. Leaves

Leaves are rich in alkaloids tested from GC-MS chromatography.

Non phenolic bases : Roemerine, anonaine, nuciferine, pronuciferine and N-nornuciferine.
Phenolic bases : N-methyl-coclaurine and armepavine (leaf extract)
benzylisoquinoline alkaloids : Norcoclaurine and coclaurine (leaf extract) [4].

4.3. Flower

Different constituents are found in various parts of stamen as follows:

Table 1: Different constituents are found in various parts of stamen

Part of a flower	Main constituent	Example
Stamen	Flavonoids 1. Glycosides	Kaempferol derivatives nelumboroside A and B
	2. isorhamnetin glycosides	3-O-β-D-glucopyranoside, isorhamnetin 3-O-a-L-rhamnopyranosyl-(1→6) -β -D-glucopyranoside
Stamen extract	Non-flavonoids	Adenine, Myo-inositol, arbutin, β-sitosterol glucopyranoside [4, 5]

4.4. Rhizome

Rhizomes are rich in mineral content hence are used as food as well as vegetable in Asian countries. Whereas, tissues are rich in starch, however fresh rhizome has 31.2% of starch with no scent or flavour. Fresh rhizome also contains 9.25% starch, 83.80% water, 0.80% fibre, 1.56% reducing sugar, 2.70% crude protein, 0.41% sucrose, 0.11% fat and 0.06% calcium. Moreover, oxalate compound in rhizome has found to be 84.3 mg in 100 g.

When the characteristic property of starch lotus was tested and compared to potato and maize starch, it is found to have a better property of disintegration and binding in pharmaceutical preparations such as tablets. Further researches reveal that rhizome's methanol extract has steroidal triterpenoid i.e. betulinic acid [4].

5. Common uses of *Nelumbo nucifera*

N. nucifera used in the treatment of leprosy, cancer, tissue inflammation, skin diseases and most prominently as an antidote of poison [6, 8-9]. However, it is used as anti-emetic, diuretic, anti-anthelmintic, nervous exhaustion and in the treatment of stanguary [10, 11, 12].

It is a source of febrifuge, astringent, demulcent and cooling property, thus considered as an herbal medicine as well as an ornamental flower. *Nelumbo nucifera* is known as sacred lotus because of religious significance however its leaves and seeds are eaten in South East Asia.

Parts used : Uses
Rhizome : Food
Seed : Medicine
Thalam1us : Fruit
Leaves : Plate
Petals : Color extraction [2].

6. Morphology of *Nelumbo nucifera*

Leaves of both types, i.e. orbicular and aerial are large [2], blue green in colour with bitter, neutral or sweet taste. According to Bensky Dan in 2004 leaves of lotus are used in resolving heat and to stop bleeding, however the research of Shoji (1987) stated that the leaves contains several flavonoids and alkaloids [13].

Fruits:

It has a notable power of dormancy. It is an indehiscent nut let but its ripe nut let are roundish or ovoid in shape has smooth hard grayish black or brownish pericarp [2]

Seeds:

N. nucifera have longevity of seeds as compared to other flowering plants [2]

According to the many research articles, the seed extract is tested on rat's isolated heart at dose from 0.1 to 30 mg/ml to induce the ischemia. Maximum upturn dose was observed at 10 mg/ml, though cardiac output was same and anti-ischemic dose has found to be 3 mg/ml [14].

Flowers:

Flowers are large 5-12.5 in radius, solitary, pinkish white or white pink arise from the nodes of the rhizomes [2].

Rhizomes:

Rhizomes are smooth 60-140 cm long, yellowish white in colour 0.5 to 2.5 cm in diameter. Found in longitudinally striated brown patches. It has indistinct odor. It has internodes and nodes. If we cut fresh rhizome it oozes out the mucilaginous juice. The fracture is observed as fibrous and tough [2].

Table 2: Pharmacological activity of various parts of lotus plant

S. No	Activity	Part of plant used	Reference(s)
1.	Aldose reductase inhibitory	Flower	[15]
2.	Anti-inflammatory	Rhizome, Seed	[16, 17]
3.	Anti-arrhythmic	Seed	[18-22]
4.	Diuretic activity	Rhizome	[23]
5.	Anti-obesity	Leaf	[24]
6.	Anti-bacterial	Flower	[25]
7.	Psycho-pharmacological	Rhizome	[26]
8.	Anti-proliferative	Seed	[27-28]
9.	Anti-oxidant	Flower, Leaves, Rhizome	[29-34]
10.	Anti-diarrhoeal	Rhizome	[35]
11.	Hepato-protective	Leaf, Seed	[36]
12.	Anti-platelet	Flower	[37]
13.	Lipo-lytic	Leaves	[38]
14.	Anti-fertility	Seed	[39]
15.	Hypo-cholesterolaemic	Leaves	[40]
16.	Anti-pyretic activity	Rhizome, Flower	[41, 42]
17.	Anti-fibrosis	Seed	[43]
18.	Hypo-glycaemic	Rhizome, Flower	[44, 45]
19.	Aphrodisiac	Flower	[46]
20.	Anti-ischaemic	Seed	[47]
21.	Cardiovascular activity	Leaves	[48]
22.	Anti-viral	Leaves, Seed	[49, 50]
23.	Immunomodulatory	Rhizome, Seed	[51]

7. Traditional Uses of *Nelumbo nucifera*:

In many persistent bodily disorders like enteritis, tissue inflammation, cancer, leucorrhea, insomnia, leprosy, dermatopathy, palpitations, spermatorrhoea, poor digestion, menorrhagia, halitosis and heart complaints seeds and fruit of the lotus are used however it is also used as a source of food in Asia. For haemostatic function seed pods are used as traditional medicine. In traditional Chinese medicine system embryo of lotus seed is used in insomnia, CVD, nervous disorders and high fever [14]. Leaves are used as an effective medicine for epistaxis, hematuria and metrorrhagia [13]. Sometimes honey is mixed with seed powder for treating cough [14].

8. Nutritional value of *Nelumbo nucifera* rhizome:

The rhizome of lotus mainly contains starch i.e. 31.2% and some traces of minerals are also found. It is used as a vegetable in Asian countries and because of the mineral content is used as healthy food. The rhizome has no characteristic taste or odour. The oxalate content of rhizome was found to be 84.3 mg/100 g. The characteristic property of starch lotus was tested and compared to potato and maize starch. It is found to have a better property of disintegration and binding in pharmaceutical preparations such as tablets. For maximum extraction of other constituents has been found with 50% volume by volume alcohol (methanol) extract, it possesses betulinic acid which is steroidal

triterpenoid. Other than the starch lotus rhizome contains crude protein, reducing sugar, fat, water, salts, sucrose, ash, niacin, thiamine, riboflavin, and asparagine like amino acid [52].By differential scanning colorimetry and microscope heating stage property of gelatinization of starch found in lotus root has been confirmed [53].

9. Importance of *Nelumbo nucifera* rhizome:

The rhizome of *Nelumbo nucifera* has medicinal importance, such as used in the treatment of dysentery [2] as a demulcent, cholagogue, nutritive, diuretic and in the treatment dyspepsia, diarrhoea, and piles [54]. However, the methanol extract possesses antipyretic, antimicrobial, antifungal, antibacterial, antidiarrhoeal and psychopharmacological effects. It was noted that the people of Assam use lotus as anti-diabetic agent during field work and because of this information preliminary test of anti-diabetic studies have been performed from which lotus's hypoglycemic activity was observed in streptozotocin induced mice. To confirm this activity lotus ethanol extract was tested on hypoglycemic and normal rats against the standard antidiabetic agent tobultamide. It gives hypoglycemic effect not only in diabetic but in normal rats as well. Extract of lotus also increases exogenous insulin, thus it is concluded that the lotus has a similar mechanism as of insulin [55].

Many times the knots are considered useless, similarly the lotus's rhizome knot was considered inedible thus wasted, but it contains polyphenol in bulk such as: B-type procyanidin dimer, H_2O, Epicatechin, Catechin, rutin, caffeic acid and propyl gallate. However, H_2O is identified as the main polyphenol in the rhizome knots permeate and extract [56].

The Rhizome of *Nelumbo nucifera* is also used as pickle, dried white slice is used as curry or fried as chips. Fresh rhizome is also roasted and used as food [57].

10. Pharmacological Activity of *Nelumbo nucifera* rhizome

10.1 Antidiarrheal activity

The methanolic extract of rhizome gives anti-diarrhoeal effect and it has been observed in several studies. It produces inhibitory effects against PGE-2 induced rats and castor oil induced diarrhoea even the active movement of a charcoal meal inhibits significantly [4].

10.2 Hypoglycaemic activity

The methanol extract of lotus was found to be responsible for hypoglycemic activity. However, this activity is also observed in the non-diabetic and streptozotocin induced rats. The extract was given orally to the streptozotocin induced diabetic mice and found effective at the dose of 300 mg/kg by 53% and 600 mg/kg by 55% to reduce the blood glucose level. In glucose fed diabetic hypoglycaemic mice the extracted tryptophan from the nodes of rhizome found effective at a dose of 400 mg/kg and 100 mg/kg, hence tryptophan is considered as anti-diabetic constituent [44, 45].

10.3 Psychopharmacological activity

The psychopharmacological effects in mice and rats are produced from the methanol extract of N. *nucifera*. According to Mehta, N.R., Patel, E.P., Patani, P.V. and Shah, B., 2013 a decrease in exploratory behaviour in Y-maze and head dip test is reported. Hence it possesses the minor tranquillizers pharmacological effects [5].

Mukherjee in 1996 reported different tests in a review article. Head dip test and Y- maze for exploratory behaviour which was inhibited. Rotarod, 30° inclined screen and traction test for muscle relaxant actions as a result it is concluded as a drop-in muscle relaxant activity however rhizome's alcoholic extract has increased the effect of pentobarbitone induced sleep [5].

10.4. Diuretic activity:

A dose dependent effect of methanol extract of the rhizome of lotus was observed at 300 mg/kg, 400 mg/kg and 500 mg/kg. With the increase of dose, the volume of urine excreted increases thus the excretion of potassium and sodium also increases (natriuresis>kaliuresis). However, comparison of extract with the standard i.e. furosemide (20mg/kg) the effect was less. Thus, alcoholic extract of rhizome possesses diuretic activity [4].

10.5 Anti-inflammatory activity

A comparable effect of methanol extract of N. *nucifera* rhizome and of steroidal triterpenoid- Betulinic acid with standard i.e. dexamethasone and phenyl-butazone has given the anti-inflammatory effect on serotonin and carrageenin induced rat paw edema at 200 mg/kg and 400 mg/kg dose [2].The dexamethasone and phenyl-butazone are prototype drugs of the anti-inflammatory. The effect of betulinic acid is observed in the rats at 50 and 100 mg/kg dose [55].

10.6 Antioxidant activity

Not only rhizome but the rhizome knot also possesses the antioxidant activity. According to a research yang and coworkers have performed some activities to study the in vitro activity of the acetone-methanol extract of the lotus rhizome by using the DPPH assay at 66.7 mg/l and 133.3 mg/l. Interestingly, it showed higher activity than ascorbic acid. By electron spin resonance and spectrophotometrically the anti-oxidant activity of rhizome knot has also tested [4, 30, 58-60].

The extracts of lotus rhizome knot and lotus leaves were proposed for meat as an anti-oxidant. The test contains three groups according to the treatment of bovine and porcine meat

i. Control group
ii. Rhizome knot extract (w/w 3%)
iii. Leaf extracts (w/w 3%)

These samples were kept at 4°C and tested at 1, 3, 6 and 10 days. Positive results were obtained when compared both part's extracts it was found that extract of

rhizome knot is more effective against lipid oxidation. Thus, from a pharmaceutical point of view, this extract can be used to increase the shelf life of meat [61].

10.7 Antipyretic activity

The yeast induced pyrexia rats showed dose dependent antipyretic activity at oral doses of the methanolic extract of N. *nucifera* rhizome at 200 mg/kg, 300 mg/kg and 400 mg/kg. The results were compared with standard antipyretic agent-Paracetamol (150 mg/kg) given intra peritoneal [4]. Usually the rectal temperature increased by the yeast suspension after 19 hr. of administration [5].

10.8 Immunomodulatory activity

By nitrobluetetrazolium reduction (NBT) test, phagocytic response and delayed type hypersensitivity (DTH) reaction, neutrophil adhesion test, total and differential leukocyte count (TLC and DLC) test were used to evaluate the immunomodulatory effect of rhizome extract of N. *nucifera* (100 and 300 mg/kg) by immunizing a practical animal (rats and mice) sheep red blood cells (SRBC, 5×109 cells/ml)

Total leukocyte count and lymphocyte count : Increased
Neutrophil count : Decreased
delayed type hypersensitivity (DTH) reaction : Potentiate

It is concluded that the N. *nucifera* potentiated the defence mechanism by the change in immunological parameters because 62.91% and 63.22% adhesion of neutrophil observed to the nylon fibres [4, 51].

10.9 Memory and Neurogenesis

Positive effects of N. *nucifera* rhizome extract were observed on learning and memory function. The test performed for evaluating this effect is step-through passive avoidance test however immune-histo-chemistry was used to determine cell differentiation and proliferation in the dentate gyrus of the hippocampus. To test the cognitive behaviour the methanol extract of *N. nucifera* rhizome (MNR) was used in Wistar rats. The methanol extract of the N. *nucifera* showed the positive effects of learning, neurogenesis and memory functions in dendategyrus a part of hypothalamus [62].

Table 3: Results

Test	Results
Passive avoidance test	The retention time of MNR-treated rats was significantly longer than that of controls.
Immunohistochemical analyses using BrdU, Ki-67, and DCX	Increased cell proliferation and cell differentiation in the dentate gyrus.

11. Uses of rhizome extract according to preparation

11.1 Tinctures of rhizome:

Standardization and evaluation of tinctures have been made. By using different strengths of alcohol, tinctures have been prepared, however the maximum number of constituents is present in 50% volume by volume alcoholic extract [5].

11.2 Powdered rhizomes:

The starch taken from the rhizome and used medicinally or for nutrition value is known as arrowroot nutrition. The rhizome of lotus used for diarrhoea and dysentery in children. Moreover, it has been prescribed for dyspepsia and as demulcent in piles, however it is used in powder form as an external preparation in ring worms and scabies [5].

12. Discussion and Conclusion

In this study we have mainly focused on the rhizome of *Nelumbo nucifera* because it possesses high economic value due to the abundance of bioactive compounds that have a miraculous health promoting effect on the human body. These bioactive compounds include: alkaloids, lipids, xanthophylls, nuciferine, phospholipids, carotenes flavonoids, aporphines etc. However, the rhizome of *Nelumbo nucifera* is most commonly used in the preparation of traditional food items most commonly in China and Asian countries. Mainly *Nelumbo nucifera* is cultivated in Japan and China, however, it is inhabitant of India, China and Japan. It is most commonly found in ponds as it is an aquatic herb. Due to its sweet fragrance of the flower it is considered as the national flower of India. *Nelumbo nucifera* is used in the treatment of leprosy, cancer, tissue inflammation, skin diseases and most prominently as an antidote of poison. This review highlights several pharmacological and phytochemical studies that have demonstrated the therapeutic potential of *Nelumbo nucifera*. This needs to be explored further through clinical studies on human volunteers to provide evidence-based therapeutics.

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