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A SYSTEMATIC REVIEW ON BOTANICAL BACKGROUND, PHYTOCHEMICAL AND PHARMACOLOGICAL PROPERTIES OF NYMPHAEA NOUCHALI

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ABSTRACT
Background: *Nymphaea nouchali* is a widely distributed aquatic plant prevalent in tropical and subtropical areas, flourishing in freshwater habitats. It is widely recognized as the water lily. Historically, it has been utilized in several medical systems to address conditions such as diabetes, liver diseases, and urinary tract issues. The plant comprises several bioactive substances, including flavonoids, phenolic acids, and alkaloids, which enhance its therapeutic qualities. This review examines the botanical, phytochemical, and pharmacological characteristics of *Nymphaea nouchali* to evaluate its medicinal potential. **Methodology:** This review combines data from previous botanical, phytochemical, and pharmacological research on *Nymphaea nouchali*. The bioactive components extracted from the plant were examined for their therapeutic capabilities. The pharmacological effects, encompassing antibacterial, antioxidant, anti-inflammatory, antinociceptive, and anticancer properties, were assessed by several in vitro and in vivo experimental methods. **Results:** A phytochemical study identified the presence of substances, including nymphal, gallic acid, and quercetin. These chemicals are associated with notable biological functions. Alkaloids and tannins had antibacterial activities, but phenolic compounds and flavonoids showed potent antioxidant capabilities. The herb demonstrated antinociceptive properties. Initial investigations suggested possible anticancer effects on some cell lines; nevertheless, further study is required. **Conclusion:** *Nymphaea nouchali* shows significant pharmacological potential due to its many bioactive components. Although traditional medicinal usage supports its therapeutic benefits, further preclinical and clinical investigations are necessary to validate its efficacy and safety for pharmaceutical uses.

INTRODUCTION

The botanical family Nymphaeaceae, the water lily family, encompasses a diverse assemblage of aquatic flowering flora. These specimens exhibit specialized adaptations for life within aquatic settings, featuring buoyant leaves and vibrant blossoms. Widely distributed across global regions, the Nymphaeaceae

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family encompasses species suited to tropical and temperate climates [1]. Characterized by rounded or oval-shaped foliage, the leaves of Nymphaeaceae plants possess a hydrophobic cuticle, affording them buoyancy and protection against water saturation. These leaves fulfill multifaceted roles within aquatic ecosystems, offering shelter, regulating water temperature, and influencing oxygenation levels. The Nymphaeaceae family is a captivating botanical ensemble, enriching freshwater environments with its aesthetic allure & ecological significance [2,3]. *Nymphaea nouchali* is a perennial aquatic herb belonging to the family Nymphaeaceae. The Ayurvedic and Siddha medical systems make extensive use of this plant for a variety of purposes, including the treatment of diabetes, inflammation, liver problems, and urinary tract illnesses; it is also used as a bitter tonic, and the plant produces globose fruits that contain seeds that are spherical and flask-shaped [4]. The seeds have medicinal and stomachic properties. In ayurvedic treatment, the seeds are also recommended for diabetics as part of a special diet. Research has shown that seeds provide many health benefits, including lowering blood sugar levels, fighting infections, and protecting the liver from damage. The seeds include alkaloids, glycosides, flavonoids, saponins, and phenols. Recently, the compound nymphasterol, an unexplored steroid, has been isolated and identified in the seeds [5,6]. For centuries, the elegance and allure of *Nymphaea nouchali* have captivated human admiration, particularly for their exquisite flowers and tuberous rhizomes [4]. Throughout antiquity, the tuberous rhizomes of Nymphaea species have served as a staple sustenance for various indigenous communities and a culinary delicacy for more sophisticated societies. Utilized as sustenance and a source of aesthetic pleasure, the tuberous rhizomes of *Nymphaea nouchali* have been embraced by underprivileged populations for their dual roles as food and medicine [7].

MATERIALS AND METHODS

A comprehensive literature review was conducted to compile pertinent data regarding *Nymphaea nouchali*, also called Bhet phool or Neel kamal. Several internet databases, including ScienceDirect, Google Scholar, PubMed, Springer Link, and Scopus, were extensively searched to locate pertinent materials." *Nymphaea nouchali*," "traditional uses," "phytochemistry," and "pharmacological activities" were some of the keywords utilized to find relevant information about the plant, among others. The synthesized data covered diverse aspects, including chemical composition, ethnopharmacology, traditional uses, ethnobotanical insights, and pharmacological properties associated with *Nymphaea nouchali*. Mendeley software facilitated the organizational process of categorizing and managing retrieved studies systematically. A few research articles were left out while the review was being produced since they did not include papers with unique methodologies or interesting conclusions. Although some items were unnecessary and relied on antiquated techniques, we had to retain them due to a lack of more recent content. After all the screenings, just 73 studies were retained out of 2,829 discovered initially. The PRISMA criteria were the target audience for creating this outline, depicted in **Figure 1**. Our knowledge and analysis of the chemical ingredients contained in *Nymphaea nouchali* were further improved by integrating chemical structures and IUPAC designations using PubChem.

Botanical background

Taxonomy

Nymphaea nouchali is classified as belonging to the most diverse genus in the family, Nymphaeaceae, under the Nymphaeales order [8]. There are perhaps 50–60 species in it. Due to their applications in food and drink production, herbal medicine, bioremediation, aquatic filtration, and flower arrangement harvesting, several Nymphaea species are economically significant. The diverse uses of Nymphaea species demonstrate their ecological and economic importance to the larger plant ecosystem [9].

Synonyms

Nymphaea species, the botanical specimen under consideration, has notable nomenclatural variability worldwide. The variety of species and cultivars found in various locations, each with distinctive traits and colloquial names, demonstrates this diversity. Water lilies are enchanted with their beauty and versatility, whether found in the vivid streams of the tropics or the tranquil ponds of colder climes. This rich tapestry of nomenclature reflects these aquatic plants' cultural and ecological importance, highlighting their widespread appeal and significance in diverse landscapes worldwide. *Nymphaea nouchali* is referred to as Shapla in Bengali [10] and Nil Manel in Sri Lanka [11]. Boga Bhet, Seluk (Assamese), Kumud, Sundi (Bengali), Poyanu (Gujarati), Bhenght, Kamal, Kanval, Koi, Koka, Kokka, Kumudini, Neel Kamal (Hindi), (Tamil), Alli Kaada, Allikada, Indeevaramu, Indivara, Neeti Tamara, Tellakaluva (Telugu), Neelofar (Urdu) [10,12,13].

Botanical description

Nymphaea nouchali thrives in clear, tepid, stagnant waters with a slight acidity. It can tolerate a range of water conditions but prefers still water. The plant is often found in ponds and tanks, contributing to the local aquatic ecosystem by providing habitat and food sources for various organisms [14]. The leaves of *Nymphaea nouchali* are long-stalked and possess a leathery texture. They vary in color from green to reddish-brown and are deeply cordate, meaning they have a heart-shaped base. The undersides of the leaves are densely hairy, providing insulation and possibly aiding in nutrient absorption.

The flowers of *Nymphaea nouchali* are fragrant and visually striking. They typically consist of 4-5 sepals and form a copular calyx. The flowers are borne on elongated peduncles, which are the stalks that support the flower. The petals are predominantly white or violet, contributing to the plant's aesthetic appeal. One of the notable features of *Nymphaea nouchali* is its remarkable stamen count, which can range between 30 and 250 per flower. This abundance of stamens may play a significant role in the plant's reproductive strategy and attractiveness to pollinators [6,15]. The picture of the whole plant and its parts are shown in Figure 2 with sub-divisions A, B, C, and D, respectively.

Traditional uses

In several regions of India, Nymphaea nouchali's rhizomes, seeds, and flowers are consumed as food. The seeds are often roasted and eaten as snacks or added to traditional dishes for their nutty flavor. The young leaves and tender stalks are vegetables in soups, stews, or curries. The flowers are cardiotonic and possess astringent qualities. The seeds are highly regarded for their medicinal and restorative capabilities and aphrodisiacal effects, cooling nature, rich flavor, and constipating impact [16].

Beyond medicinal applications, Nymphaea has been incorporated into culinary practices, serving as a staple food and offering therapeutic benefits. In Ayurveda, *Nymphaea nouchali* has been used to treat various ailments such as diarrhea, dysentery, fever, and inflammation [17]. This plant is globally valued for medicinal and culinary purposes. They treat kidney diseases, piles, and cardiac disorders [18]. In Egyptian culture, the Nymphaea species is used in shamanistic rituals and health-related practices. In ancient Greece and Rome, it was referred to as the essence of beauty and holiness [19].

Symbolism

Nymphaea nouchali is the national flower of Bangladesh and Sri Lanka. Across antiquity, its exquisite blossom has symbolized values of virtue, harmony, and purity, chronicled in historical texts in Sanskrit, Pali, and Sinhala, known variably as Kuvalaya, Indhiwara, Niluppala, Nilothpala, and Nilupul. Within Buddhism, it carries significance as one of the 108 symbols adorning the footprints of Prince Siddhartha, later revered as Gautama Buddha. Legend recounts that lotus flowers unfurl wherever Buddha journeyed in his lifetime and even after his passing. The dark complexion of Lord Krishna is likened to the Neel Kamal, hence known as Krishna Kamal. Revered as one of Goddess Durga's favored blooms, it holds significance in Hindu mythology. In the Krittivas Ramayans, it is recounted that Lord Rama sought blessings from Goddess Durga before battling Ravana to rescue his abducted wife, Sita. He endeavored to present 108 Neel Kamal flowers to the Goddess but found one missing. Overwhelmed with devotion, he offered his eye, resembling the flower. Goddess Durga, moved by his passion, blessed him for victory. Today, Neel Kamal flowers are still offered to Goddess Durga during Durga Puja [10].

PHYTOCHEMISTRY

Many chemicals have been extracted and identified from various portions of *Nymphaea nouchali*. Table 1 lists some of the bioactive chemicals found in Nymphaea nouchali**.**

PHARMACOLOGICAL ACTIVITY

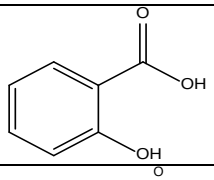
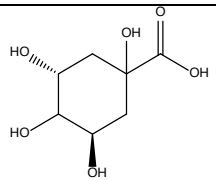
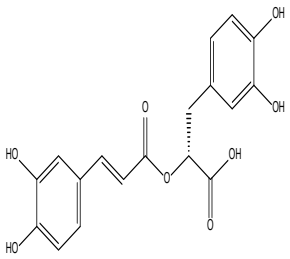
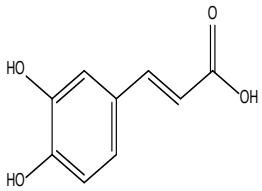
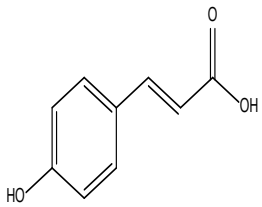
Numerous researchers have elucidated the diverse biochemical activities exhibited by *Nymphaea nouchali* across a spectrum of *in-vivo* and *in-vitro* test models. Reports document its multifaceted therapeutic potential, including antibacterial, antioxidant, antinociceptive, antimicrobial, and anticancer.

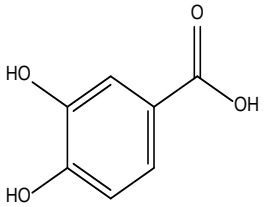
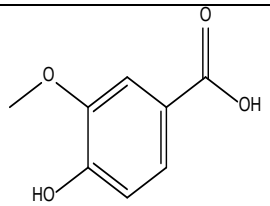
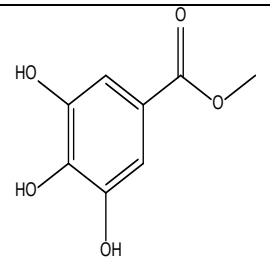
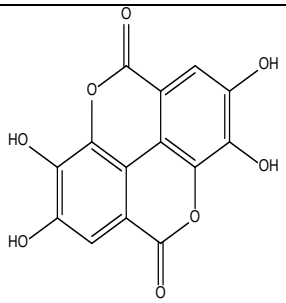
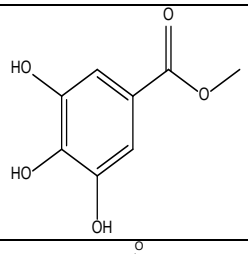
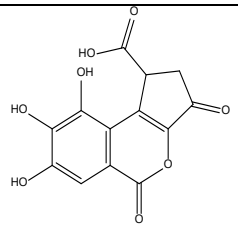
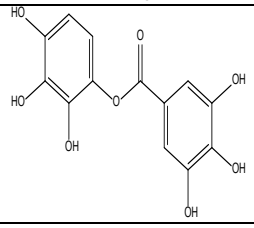
Antibacterial activity

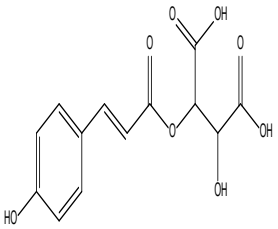
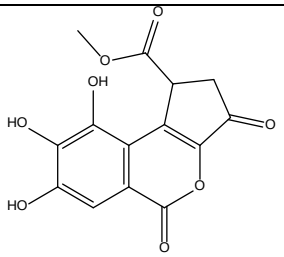
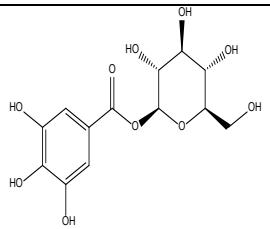
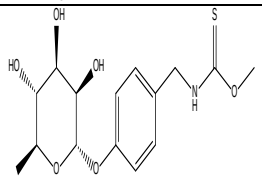
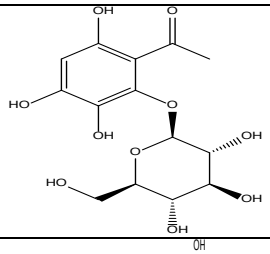
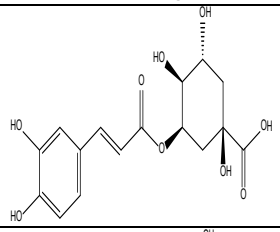
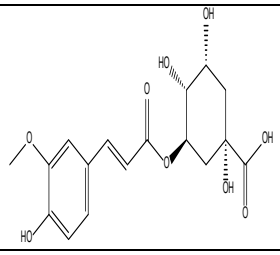
The attributed antibacterial efficacy is believed to be due to their secondary metabolites, notably alkaloids, tannins, saponins, and flavonoid compounds. These constituents have been previously acknowledged for their antimicrobial properties. Consequently, it is plausible to surmise that the extracts derived may exhibit therapeutic potential against infections elicited by the inhibited bacterial strains. Furthermore, the findings elucidated a notable alignment between the documented utilization of *Nymphaea nouchali* in traditional medicinal practices for addressing infectious ailments and its observed *in vitro* efficacy. In

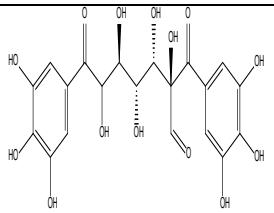
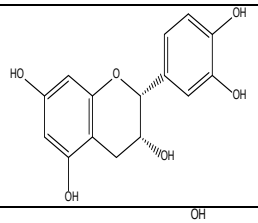
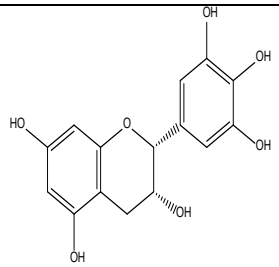
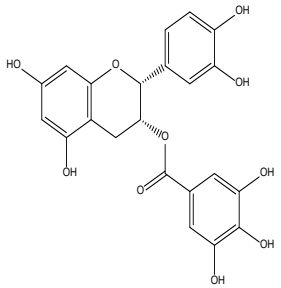
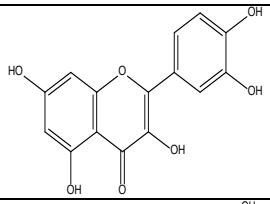
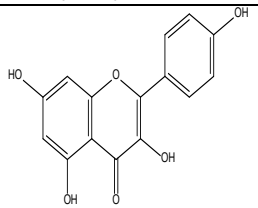
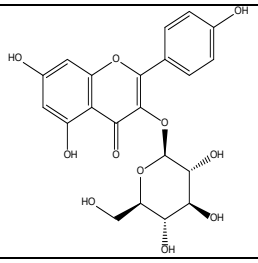
comparison to the synthetic quinolone antibiotic nalidixic acid, which is known for its broad-spectrum effectiveness, the methanolic extract of *Nymphaea nouchali* flowers showed improved antibacterial activity against *Bacillus subtilis* and *Staphylococcus lutea*. Notably, the antibacterial efficacy of the methanol extract exhibited an improvement of 11% against *Bacillus subtilis* and 27% against *Staphylococcus lutea* compared to the antibiotic [65]. Plants represent vital reservoirs of pharmacophores with promising prospects for developing innovative chemotherapeutic agents [66]. A study was conducted on *Nymphaea nauchali* rhizome extract against different bacteria, which showed suitable anti-bacterial activity. In the presence of rhizome peels acetone RPA (18±0.21mm) followed by RPM extract (16±0.05mm) and RPE (15.5±0.01mm) the growth of *Pseudomonas aeruginosa* was inhibited. The growth of *Pseudomonas vulgaris* and *Escherichia coli* was inhibited indifferently by peel extract and core extract. The zone of inhibition of RPE, RPM, and RPA was high against *Enterococcus faecalis.* Of the three inner core extracts, RICA extract shows the highest zone of inhibition (14±0.02mm) against CONS and *Staphylococcus aureus*. The two gram-negative bacteria, *Pseudomonas aeruginosa* and *Pemphigus vulgaris*, showed resistance to ampicillin at the studied concentration, while *Escherichia coli* showed moderate sensitivity to ampicillin. At 30μgml^{-1}, all the gram-positive test bacteria resisted methicillin [67].

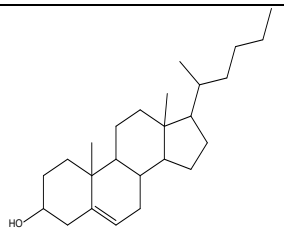
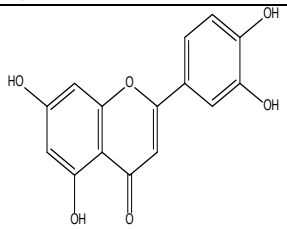
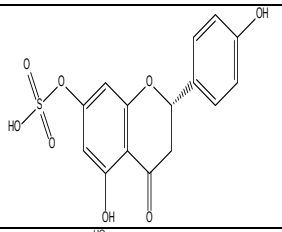
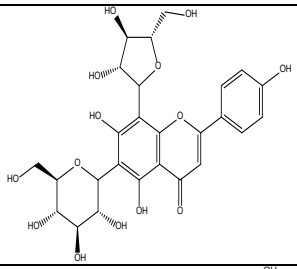
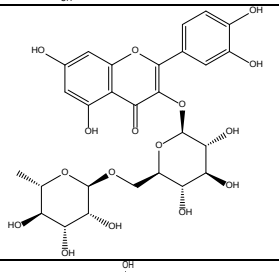
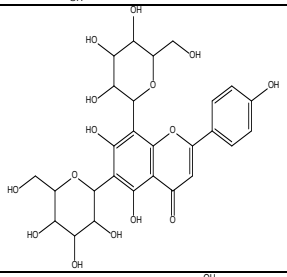
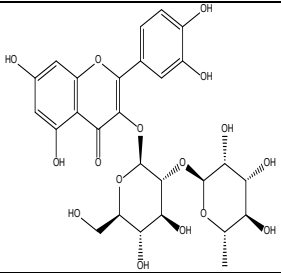
Table 1: Isolated compounds from *Nymphaea nouchali*

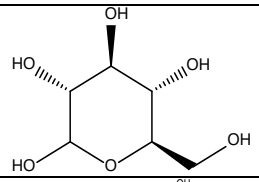
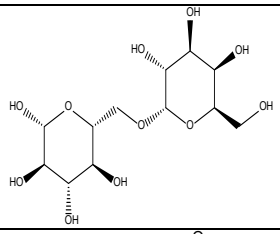
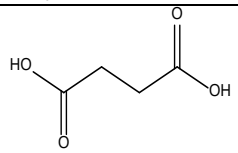
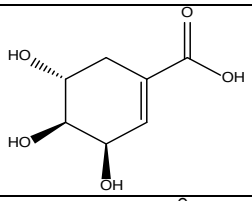
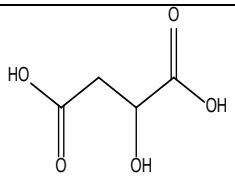
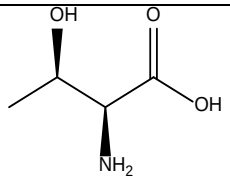
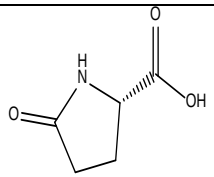
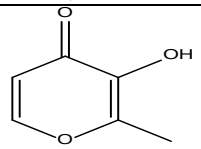
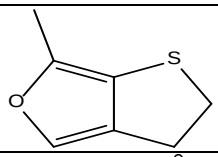
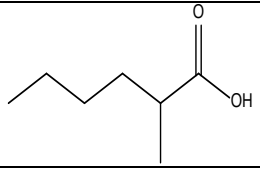
Group	S No.	Compound Name	Chemical formula	Mw (g/mol)	Structure	Pharmacological activity	Reference
Phenolic Compound	1	Salicylic acid	$C_7H_6O_3$	138.12		Anti-inflammatory, Antihyperglycemia, Analgesic, Antipyretic, Antiseptic	[20–22]
	2	Quinic acid	$C_7H_{12}O_6$	192.17		Anticancer, immunomodulator, Anti-fungal, Antioxidant, Neuroprotective	[20,23, 24]
	3	Rosmarine acid	$C_{18}H_{16}O_8$	360.3		Anti-alzheimer's, Anticancer Antidiabetic, Antimicrobial, Cardioprotective, Anti-ageing, Anti-inflammatory, Antiallergic, Anti-depressant	[25–27]
	4	Caffaic acid	$C_9H_8O_4$	180.16		Antioxidant, Antimicrobial, Anticancer, Anti-alzheimer's, Antiviral, Antidiabetic, cardioprotective, hepatoprotective, anti-atherosclerotic	[28,29]
	5	p-coumaric acid	$C_9H_8O_3$	164.16		Anti-inflammatory, Antioxident, Gastroprotective, Antidiabetic, Anti-hyperlipidemia, Anti-tyrosinase, Anti-cancer, Hepatoprotective	[25,30,31]

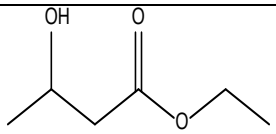
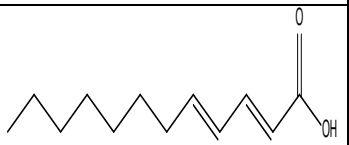
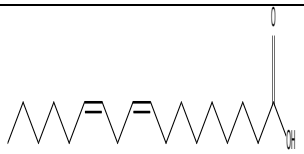
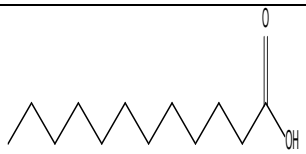
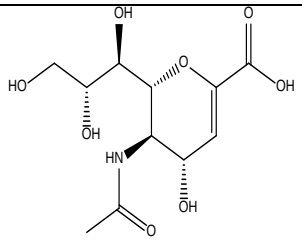
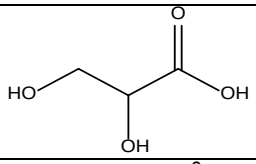
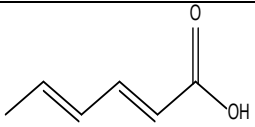
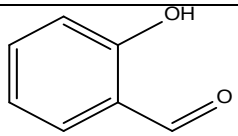
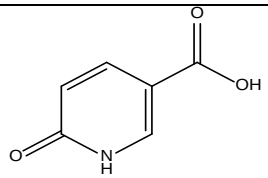
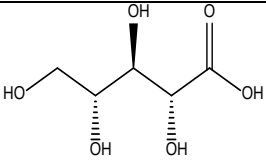
Group	S No.	Compound Name	Chemical formula	Mw (g/mol)	Structure	Pharmacological activity	Reference
	6	Protocatechuic acid	$C_7H_6O_4$	154.12		Antioxidant, Anti-inflammatory, Neuroprotective, Antibacterial, Antiviral, Anticancer, Antiosteoporotic, Analgesia, Antiaging activties	[20,32]
	7	Vanillic acid	$C_8H_8O_4$	168.15		Anticancer, Antiobesity, Antidiabetic, Antibacterial, Anti-inflammatory, Antioxidant effects	[20,25,33]
	8	Gallic acid	$C_7H_6O_5$	170.12		Anti-inflammatory, Anti-tumor, Anti-bacterial, Anti-diabetes, Anti-obesity, Anti-microbial and Anti-myocardial ischemia	[20,25,28, 34,35]
	9	Ellagic acid	$C_{14}H_6O_8$	302.19		Antioxidant, Anti-hepatotoxic, Anti-steatosic, Anti-cholestatic, Anti-fibrogenic, Anti-hepatocarcinogenic, Antiviral	[25,36]
	10	Methoxygallate	$C_8H_8O_5$	184.15		Anti-tumor, Anti-inflammatory, Anti-oxidant, neuroprotective, hepatoprotective and Anti-microbial activities	[20,37]
	11	Brevifolin carboxylic acid	$C_{13}H_8O_8$	292.20		Anti-oxidant, Anti-bacterial, Anti-cancer, Anti-inflammatory.	[20,38]
	12	Pyrogallol gallate	$C_{13}H_{10}O_8$	294.21		Anti-oxidant, Anti-fungal, Anti-psoriatic	[20,39]

Group	S No.	Compound Name	Chemical formula	Mw (g/mol)	Structure	Pharmacological activity	Reference
	13	ρ-coumaroyl tartaric acid	$C_{13}H_{12}O_8$	296.23		antioxidant, anti-cancer, antimicrobial, antivirus, anti-inflammatory, antiplatelet aggregation, anxiolytic, antipyretic, analgesic, anti-arthritis activities.	[20]
	14	Methyl Brevifolin carboxylic acid	$C_{14}H_{10}O_8$	306.22		Antioxidant	[20]
	15	Galloyl glucose	$C_{13}H_{16}O_{10}$	332.26		Anti-cancer, Anti-diabetic	[20]
	16	Niazinin	$C_{15}H_{21}NO_6S$	343.4		Antiproliferative, Leishmanicidal, anti-inflammatory and anti-pyretic activity.	[20,40]
	17	Lalioside	$C_{14}H_{18}O_{10}$	346.29		Anti-bacterial	[20,41]
	18	5-O-caffeoylquinic acid	$C_{16}H_{18}O_9$	354.31		Anti-microbial, Anti-oxidant	[20,42,43]
	19	3-Feruloylquinic acid	$C_{17}H_{20}O_9$	368.3		Anti-inflammatory, Anti-oxidant	[20]

Group	S No.	Compound Name	Chemical formula	Mw (g/mol)	Structure	Pharmacological activity	Reference
	20	Digalloyl glucose	$C_{20}H_{20}O_{14}$	484.4		Anti-oxidant, Anti-inflammatory Anti-microbial, Potential Anti-cancer.	[20,44]
Flavonoids	21	Catechin	$C_{15}H_{14}O_6$	290.27		Anti-oxidant, Anti-inflammatory, Antidiabetic, Anti-cancer, Neuroprotective effect.	[20,45]
	22	Epigallocatechin e	$C_{12}H_{14}O_7$	306.27		Antineoplastic, Antioxidant	[28]
	23	Epicatechine gallate	$C_{22}H_{18}O_{10}$	442.4		Antiaging, Antibacterial, Anticaries, Antidiabetic, Analgesic, Antidiarrheal, Antifibrotic, Anti-inflammatory, Antioxidative, Antiparkinsonism, Antistroke, Antiatherosclerotic, Anticancer	[28,46]
	24	Quercetin	$C_{15}H_{10}O_7$	302.23		Antioxidant, Anti-aging, Anti-inflammatory, Anti-allergic	[17,47]
	25	Kaempferol	$C_{15}H_{10}O_6$	286.24		Antioxidant, Anti-inflammatory, Anti-cancer, Anti-obesity	[28,47,48]
	26	Astragalin	$C_{21}H_{20}O_{11}$	448.4		Anti-oxidant, Anti-inflammatory, Anticancer, Anti-diabetic, Anti-ulcer, Anti-obesity, Anti-osteoporotic, Cardioprotective	[49,50]

Group	S No.	Compound Name	Chemical formula	Mw (g/mol)	Structure	Pharmacological activity	Reference
	27	Nymphayol	$C_{25}H_{42}O$	358.6		Anti-nociceptive, Anti-inflammatory, Antipyretic, Antidiabetics, immunomodulatory.	[51,52]
	28	Luteoline	$C_{15}H_{10}O_6$	286.24		Anti-alzheimer's, Anti- cancer	[28,53,54]
	29	Naringenin-7-sulfate	$C_{15}H_{12}O_8S$	352.3		Anti-oxidant, Anti-estrogenic, Anti-obesity, Anti-diabetic, Anti-bacterial, Anti-cancer	[20,55]
	30	Apigenin-6-C-galactoside-8-C-arabinoside	$C_{26}H_{28}O_{14}$	564.5		Antiproliferative activity.	[20]
	31	Rutin	$C_{27}H_{30}O_{16}$	610.5		Antioxidation, Anti-inflammatory, Anti-diabetic, Anti-adipogenic, neuroprotective	[28,56]
	32	Vicenin-2	$C_{27}H_{30}O_{15}$	594.5		Anti-oxidant, Anti-inflammatory, Anti-cancer, Anti-proliferative, Hepatoprotective activity	[20,57]
	33	Quercetin-3-neohesperidoside	$C_{27}H_{30}O_{16}$	610.5		Anti-inflammatory activity.	[20]

Group	S No.	Compound Name	Chemical formula	Mw (g/mol)	Structure	Pharmacological activity	Reference
	34	Glucose	$C_6H_{12}O_6$	180.16		Hypoglycemic Activity.	[20]
	35	Melibiose	$C_{12}H_{22}O_{11}$	342.30		Antiproliferative, Immunomodulatory, Antifungal, Antiviral.	[20]
Carboxylic acids	36	Succinic acid	$C_4H_6O_4$	118.09		Anti-inflammatory, Antibacterial, Antithrombotic, Cardioprotective	[20,58]
	37	Shikimic acid	$C_7H_{10}O_5$	174.15		Anti-inflammatory, Analgesic, Antioxidant activities	[20,59]
	38	Malic Acid	$C_4H_6O_5$	134.09		Acidulant, Antioxidant flavoring agent.	[20]
	39	Threonine	$C_4H_9NO_3$	119.12		Lipotropic activity.	[20]
Amino acids	40	Pyroglutamic acid	$C_5H_7NO_3$	129.11		Anti-oxidant, Neuroprotective Effects.	[20]
Flavoring agents	41	Maltol	$C_6H_6O_3$	126.11		Anti-oxidant, Anti-inflammatory, Anti-tumor, Anti-diabetic	[20,60]
	42	Kahweofuran	C_7H_8OS	140.20		Anti-angiogenic and Anti-inflammatory activities.	[20]
Fatty acids	43	Methylhexanoic acid	$C_7H_{14}O_2$	130.18		Anticonvulsant, Anti-anxiety agent.	[20]

Group	S No.	Compound Name	Chemical formula	Mw (g/mol)	Structure	Pharmacological activity	Reference
	44	Ethyl-3-hydroxybutyric acid	$C_6H_{12}O_3$	132.16		Antiepileptic, Potent Ketone Body Analog properties.	[20]
	45	Caprylic acid	$C_8H_{16}O_2$	144.21		Anti-inflammatory, Antifungal	[20,61]
	46	Dodecadienoic acid	$C_{12}H_{20}O_2$	196.29		Anti-inflammatory, Anti-oxidant.	[20]
	47	Linoleic acid	$C_{18}H_{32}O_2$	280.4		Anti-tuberculosis, Anti-carcinogen, Anti-atherosclerotic, Anti-obesity	[6,62,63]
	48	Dodecanoic acid	$C_{12}H_{24}O_2$	200.32		Anti-bacterial, Anti-fungal, Anti-tumour, Anti-inflammatory, Antiviral	[20,64]
Sialic acid	49	2-Deoxy-2,3-dehydro-N-acetyl-neuraminic acid	$C_{11}H_{17}NO_8$	291.25		Potent neuraminidase (sialidase) inhibitor.	[20]
Others	50	Glyceric acid	$C_3H_6O_4$	106.08		Anti-apoptotic, Antiviral.	[20]
	51	Sorbic acid	$C_6H_8O_2$	112.13		Anti-fungal, Anti-microbial.	[20]
	52	Salicylaldehyde	$C_7H_6O_2$	122.12		Anti-nociceptive activity	[20]
	53	Hydroxynicotinic acid	$C_6H_5NO_3$	139.11		Potential Antimicrobial, Anti-inflammatory, Antioxidant properties.	[20]
	54	Ribonic acid	$C_5H_{10}O_6$	166.13		Anti-Cholinesterase	[20]

Antioxidant activity

Nymphaea nouchali tuber (WLT) has been demonstrated to have notable antioxidant properties. *Nymphaea nouchali* was found to be a good source of natural antioxidants, which was seen as free radical scavenging activity (87.7%), total phenolic content was 0.188 mg GAE/gm, and vitamin C content of 5.78%. Hence, it can be said that a good content of bioactive compounds provides different medical and health benefits [68]. Using Phyto metabolomic analysis, researchers evaluated the antihyperglycemic and antioxidative stress characteristics of boiling rhizomes from Nymphaea nouchali. The research utilized sophisticated analytical methods such as UPLC-Q-TOF-MSE, LC-QqQ-MS, and GC-MS. The investigation revealed that the rhizome included many antioxidant and antidiabetic chemicals. It is worth mentioning that the boiling rhizome powder effectively reduced sugar-induced postprandial hyperglycemia in rats. It also prevented hyperglycemia-induced hemoglobin and insulin glycation. Rhizome displayed potent reducing power and effectively scavenged various reactive oxygen species. It demonstrated antioxidant activity and antioxidative stress potential by preventing membrane lipid peroxidation in reducing H_2O_2-induced erythrocyte hemolysis. This study highlights the boiled rhizome of *Nymphaea nouchali* as a promising dietary intervention for managing hyperglycemia and associated oxidative stress [69]. The pharmacological significance of *Nymphaea nouchali* lies in its rich content of bioactive compounds, particularly flavonoids and phenolic acids, which have been shown to possess potent antioxidant properties. These compounds reduce oxidative stress by scavenging free radicals, thereby protecting cells from oxidative damage. Studies have demonstrated that the flavonoids and phenolic acids in *Nymphaea nouchali* exhibit significant antioxidant activity, with a reported reduction in oxidative stress markers of up to 40% at statistically significant levels ($p < 0.05$) Statistical confidence, such as p-values or confidence intervals is crucial for validating these pharmacological effects providing a robust foundation for the potential therapeutic applications of *Nymphaea nouchali* in oxidative stress-related conditions [70].

Antinociceptive activity

Researchers employed heat-induced (tail immersion test) and chemical-induced (acetic acid-induced writhing) pain models to examine the antinociceptive potential for the extract of methanol of *Nymphaea nouchali* (MENN) flowers [71]. Experimental concentrations of 200 mg/kg and 400 mg/kg of MENN showed substantial and dose-dependent antinociceptive effects across both tests. Comparing MENN to the reference medication Diclofenac Sodium, it showed inhibition rates of 59.97% at lower dosages and 64.75% at higher doses in the acetic acid-induced writhing test. Also in the hole cross and open field tests, MENN showed less locomotor activity, which indicates CNS depressing action. This research lends credence to the long-standing belief that the blossoms of *Nymphaea nouchali* may alleviate a wide range of aches and pains caused by central nervous system ailments [5].

Antimicrobial activity

According to published research, the aquatic plant Nymphaea nouchali is home to several endophytic fungi that may produce antibacterial compounds. There is still hope for finding new physiologically active compounds in additional active endophytic fungal extracts, even though RDNM-04's chaetoglobosin A and chaetoglobosin C isolations verified the existence of recognized compounds [72]. *Nymphaea nouchali* is recognized for its capacity to synthesize diverse secondary metabolites crucial for defense mechanisms. Recent attention has been directed toward the health-promoting attributes of these compounds, particularly their antimicrobial properties. The extract's antimicrobial effectiveness was evaluated through agar disc diffusion assay and MIC determination against various human pathogenic microorganisms. Standard antibiotics, streptomycin, and amphotericin B served as benchmarks. Additionally, HPTLC facilitated the identification and quantification of phenolic compounds. Substantial inhibition zones were noted for *Pseudomonas aeruginosa*, *Staphylococcus aureus*, and *Candida albicans*. MIC values were notably low for bacteria like *Klebsiella pneumoniae*, *Shigella dysenteriae*, and *Escherichia coli* and for fungi including *Candida albicans* and *Trichophyton mentagrophytes*. Phenolic compound quantification revealed catechin as the most abundant, followed by gallic acid and quercetin [34].

Anti-cancer activity

Research on the possible anticancer effects of *Nymphaea nouchali* flowers has been conducted on Swiss albino mice induced with EAC. Mice were inoculated with EAC cells and then given NNDM flower extract at doses of 200 and 400 mg/kg for 9 days, along with 20 mg/kg of 5-fluorouracil. Compared to the EAC control group, the study focused on variables such as the rate of tumor development, the length of time a person

lived, biochemical estimates, hematological parameters, and antioxidant activity in liver tissue. Further, the MTT test was used to evaluate the viability of cancer cell lines (HeLa, MCF-7, MDA-MB 231). Therefore, the results show that NNDM effectively inhibited EAC tumor growth in Swiss albino mice. When tested using the MTT assay, it considerably influenced the viability of cancer cells, including HeLa, MCF-7, and MDA-MB 231 cells. Additionally, the DNA laddering test was used to assess NNDM's effect on HeLa cell viability and apoptosis induction after agarose gel electrophoresis and ethidium bromide staining, and a clear ladder pattern was observed [18].

Toxicology

The biochemical and toxicological profile of *Nymphaea nouchali* flowers was examined in a study, highlighting the flowers' potential as a food additive and revitalizer. To ensure the safety of natural goods, toxicity studies are crucial. In animal models, the researchers investigated the cytotoxicity, acute toxicity, and long-term safety. Low cytotoxic effects on cell lines from the survey indicate minor direct cellular damage. In contrast, chronic toxicity studies showed no organ-specific toxicity or notable physiological disruptions, and acute toxicity testing showed no appreciable negative effects at tested levels. Additionally, the lack of mutagenic or genotoxic effects demonstrated the safety of *Nymphaea nouchali* flowers. These results support their usage in functional foods and nutraceuticals by confirming their non-toxic nature [73].

DISCUSSION

Nymphaea nouchali adds beauty to freshwater habitats such as ponds, lakes, and marshes. Beyond its aesthetic appeal, this plant holds cultural importance in many regions where it is native, often featuring in religious rituals, folklore, and traditional medicine practices. In addition to its cultural significance, *Nymphaea nouchali* plays a vital ecological role in aquatic ecosystems. Its floating leaves provide shade and habitat for aquatic organisms, while its flowers attract pollinators such as bees and butterflies. Furthermore, water lilies help improve water quality by absorbing excess nutrients and providing oxygen through photosynthesis. From a botanical perspective, *Nymphaea nouchali* exhibits intriguing features, including its unique flower structure and adaptation to aquatic environments. Research into its taxonomy, genetics, and physiological adaptations continues to deepen our understanding of this fascinating plant species.

Overall, *Nymphaea nouchali* symbolizes natural beauty, resilience, and interconnectedness within aquatic ecosystems, highlighting the importance of conserving and appreciating our planet's rich biodiversity. The pharmacological characteristics of the bioactive chemicals found in *Nymphaea nouchali* have been the subject of much research. Among the several chemicals extracted from *Nymphaea nouchali* are: Flavonoids, gallic acid, astragalin, quercetin, kaempferol, and nymphayol were discovered in the flowers. In *Nymphaea nouchali* seeds, phenols, tannins, flavones, reducing sugars, glycosides, saponins, alkaloids, and steroids were identified by the phytochemical study. These isolated compounds from *Nymphaea nouchali* have been the subject of pharmacological research aiming to elucidate their therapeutic potential and develop novel drug candidates for various diseases.

CONCLUSION

In summary, the thorough examination of *Nymphaea nouchali* in the text highlights its botanical, chemical, and pharmacological characteristics, emphasizing its importance as an aquatic plant with notable medicinal properties. 10-Eicosenoic acid and linoleic acid were isolated from the n-hexane extract while 7,8-dihydroxy α-tocopherol-9-O pyranoside, quercetin-3-O-alpha-rhamnoside, and kaempferol were extracted from the ethyl acetate fraction. Vasicinone was obtained for the first time from the ethanolic extract of *Nymphaea nouchali* flowers. Additionally, a new steroid, named nymphasterol was recently isolated from the methanolic fraction. To better understand how its active components contribute to health benefits, conducting additional preclinical studies with animal models followed by clinical trials is crucial. The ongoing exploration and research in this area show great potential for revealing the full range of therapeutic effects of *Nymphaea nouchali*, paving the way for its utilization in the healthcare and pharmaceutical sectors.

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NIL

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTION

Koushik Nandan Dutta conceptualized the article's original idea. Himshikhar Sarma and Gunjan Sahariah performed the literature review. Abhilash Bharadwaj, Dipjyoti Sharma, and Pollobi Porasar contributed to the data compilation and manuscript preparation. All authors have read and approved the final manuscript.

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ABBREVIATION

MW- Molecular Weight
RPA- rhizome peels acetone
RPM- rhizome peels methanol extract
RPE- rhizome peel ethanol extract
RICA- rhizome inner core acetone extract
CONS- coagulase-negative *Staphylococcus aureus*
WLT- Water Lily Tuber
GAE- Gallic Acid Equivalent
UPLC-Q-TOF-MSE - Ultra-Performance Liquid Chromatography coupled with Quadrupole Time-of-Flight Mass Spectrometr.
LC-QqQ-MS- Liquid chromatography coupled with quadrupole-quadrupole mass spectrometry.
GC-MS- Gas Chromatography Mass Spectrometry
GAE- Gallic Acid Equivalent
MENN- Methanolic Extract *Nymphaea nouchali*
CNS- Central Nervous System
RDNM-04- *Chaetomium globosum*
MIC- Minimum Inhibitory Concentration
HPTLC- High Performance Thin Layer Chromatography
EAC- Ehrlich ascites carcinoma
HeLa- Henrietta Lacks
MCF-7- Michigan Cancer Foundation 7
MDA-MB 231- M D Anderson - Metastatic Breast - 231
NNDM- *Nymphaea nouchali* Methanolic extract
MTT- (3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide) assay