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REVIEW

Phytochemistry and Pharmacology of the Genus Nymphaea

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Abstract

Nymphaea (Nymphaeaceae) is the most fascinating aquatic plants being consumed as food and recognized in traditional system of medicine for the treatment of various life threatening diseases. The different plant parts of the species belonging to *Nymphaea* are consumed as food in different countries globally. This review focuses on the genus *Nymphaea* and provides updated information on its botanical description, ethnopharmacology, pharmacognosy, phytoconstituents and its pharmacological aspects in health benefits. The detailed profiling of phytoconstituents from *Nymphaea* showed the structural diversity of unique and novel biochemical moiety that may provide a rich source of lead molecules for combating the human diseases in health benefits. In addition the compiled data will provide a way for the researchers to unlock the different targeted molecular mechanisms involved in the pathogenesis of various oxidative stress mediated diseases.

Keywords: Nymphaea, aquatic plants, traditional medicine, ethnopharmacology, phytoconstituents.

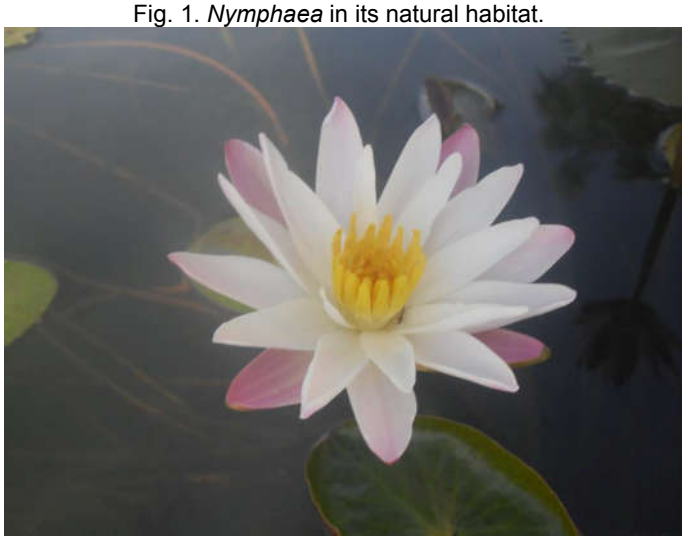
Introduction

The aquatic plant water lily is regarded as the queen of Indian flowers, beloved of the poets. The species belong to *Nymphaea* are prized as ornamentals, being considered as a religious plant and also have been introduced and naturalized outside of their active habitats (Fig. 1). *Nymphaea* occur almost worldwide, comprising 45-50 species. The tender leaves, peduncles, flowering stalks is being consumed as vegetable. Starchy rhizomes are eaten as raw or boiled. The pistils are used with black pepper for both external and internal purpose. Decoction of flowers is effective in combating thirst. The seeds are made into flour which is mixed with wheat or barley flour. In India, the Ethnic community consumes root and seed as a diet named Dhapar Koki. The root stock is eaten after boiling and mixing it with milk and sugar (Nardkarni, 2001). The peduncles and tender leaves are also used as ingredients in salad. Boiled rhizomes and parched seeds are eaten in times of scarcity. Dried seeds are made into flour which is mixed in wheat flour for making bread in China and East Indies. It is boiled and eaten in the Phillipine islands. Rhizomes are employed for tanning purpose (Jayaweera, 1982). This review on the genus *Nymphaea* gives a detailed account of updated information on the botanical description, phylogenetic studies, geographical distribution, ethnopharmacology, and more about the phytochemical and pharmacological aspects.

Botanical description

The paleobotanical studies support the view that ANITA clads (Ambrorellaceae, Nymphaeales, Illiciales, Trimeniaceae, Austrobaileyaceae) were the first line to diverge from the main branch of the angiosperm phylogenetic tree. Nymphaeaceae is a primitive family; the fossil record goes back to the early cretaceous period. The family Nymphaeaceae comprises of six genera such as *Barclaya*, *Euryale*, *Nuphar*, *Nymphaea*, *Ondinea* and *Victoria*. *Nymphaea* is the most speciose, phenotypically diverse and geographically widespread genus of Nymphaeales (Borsch *et al*., 2007).

Fig. 1. *Nymphaea* in its natural habitat.



Taxonomical hierarchy states that it belongs to kingdom Plantae, Phylum Embryophyta, Class Dicotyledons, Order Nymphaeales, Family Nymphaeaceae, Genus *Nymphaea*.

The floral description of the flowers states that it is actinomorphic, bisexual, calyx four, carolla five plus five, andrecium and gynecium infinity. The phylogenetic studies of the genus *Nymphaea* is based on the chloroplast trnT-trnF region and the genus divided into six subgenera such as *Anecphya*, *Ondinea, Brachyceras*, *Hydrocallis*, *Lotos* and *Nymphaea* (Borsch *et al*., 2007). *Nymphaea* is common in shallow lakes and ponds distributed throughout temperate and tropical Asia namely Bangladesh, India, Pakistan, Sri Lanka, Yunnan, Taiwan, Philippines, Cambodia, Laos, Myanmar, Thailand, Vietnam, Indonesia and Malaysia.

Ethnopharmacology

The powdered root stock is given for dyspepsia, diarrhea, piles and urinary ailments. A decoction of the flower is given for palpitation of the heart. It is also supposed to be a blood purifier and aphrodisiac. The rhizome is prescribed for cystitis, nephritis, enteritis, fevers and insomnia (Jayaweera, 1982). The whole plant is being used for the treatment of diabetes and eyedisorder. In Africa, the different species of *Nymphaea* is being used in the management of cancer (Sowemimo *et al*., 2007).

Pharmacognostic studies

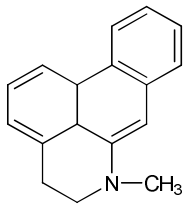
Floral Biology and ovule and seed ontogeny of Nymphaea thermarum: Flowers and fruits were processed for bright field, epifluorescence and confocal microscopy. Flower morphology with emphasis on the timing of male and female functions was correlated with key developmental stages of the ovule and the female gametophyte. Development of the seed tissues and dynamics of polysaccharide reserves in the endosperm, perisperm and embryo were examined. Pollen release in *Nymphaea thermarum* starts before the flower opens. Cell walls of the micropylarnucellus show layering of callose and cellulose in a manner reminiscent of transfer cell wall patterning. The surrounding maternal perisperm occupies the majority of seed volume and accumulates starch centrifugally. In mature seeds, a minute but fully developed embryo is surrounded by a single, persistent layer of endosperm. Early male and female function indicates that *Nymphaea thermarum* is predisposed towards self-pollination, a phenomenon that is likely to have evolved multiple times within *Nymphaea*. While formation of distinct micropylar and chalazal developmental domains in the endosperm, along with a copious perisperm, characterize the seeds of most members of the Nymphaeales, seed ontogenies vary between and among the constituent families. Floral biology, life history traits and small genome size make *Nymphaea thermarum* uniquely promising as an early-diverging angiosperm model system for genetic and molecular studies (Povilus *et al*., 2015).

Taxonomical study: The diagnostic features for the fruits and seeds of *Nymphaea* and *Nuphar* collected from Poland, Latvia and Estonia were studied. The examined organs were observed through an optic microscope and scanning electron microscope (SEM). New diagnostic features were discovered. Spotting of fresh pericarp, the range of the fruit shape coefficient, the colour of the rays in the fruit stigma disc, the thickness of the seed testa, ribs in the seeds, and occurrence of the puzzle shaped cells on the surface of the testa is observed. The discovered features were used in the taxonomic identification (Latowski *et al*., 2014).

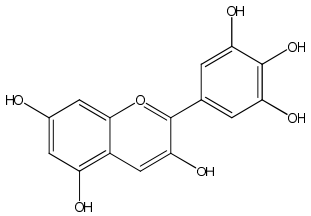
Phytochemistry: The different classes of phytomolecules such as alkaloids, glycosides, flavonoids glycosides, hydrolysable tannins, lignans, phytosterols and triterpene saponins are found to be present in the various species of the genus *Nymphaea*. Different phytochemical constituents present in Nymphea are shown in Fig. 1. The alkaloids such as Nupharidin and Apomorphine based compounds were reported from the flowers of *Nymphaea ampla* (Emboden, 1982). Nupharin and Nymphaeine were reported from the flowers of *Nymphaeaalba* (Joshi *et al*., 1974). Two phenolic base alkaloids Coclaurine reported from the aerial parts of *Nymphaea stellata* (Rastogi and Mehrotra, 1995). The cardiac glycoside Nymphalin is reported from the alcoholic flower extract of *Nymphaea alba* (Joshi *et al*., 1974). The flavonoids such as anthocyanins, flavonols and flavones were reported and present as flavonoid glycoside with various glycone moiety among the various species of the genus *Nymphaea*. Presence of dimonoside, galactoside, galactopyranoside attached with Delphinidin were reported from the blue flowers of *Nymphaea gigantean* (Maud and Robinson, 1934), leaves of *Nymphaea candida* (Bendz and Jonson, 1971), leaves of *Nymphaeax marliaceae* (Fossen and Anderson, 1997) and red flowers of *Nymphaea marliaceae* Var. Escarboucle (Fossen and Harsen, 1998). Presence of galactoside, galactopyranoside attached with Cyanidin was reported from the leaves of *Nymphaea candida* (Benz and Jonsson, 1971) and red flowers of *Nymphaea marliaceae* Var. Escarboucle (Fossen *et al*., 1998).

Presence of rhamnoside, galactopyranoside, glucoside attached with Myricetin were reported from the blue flowers of *Nymphaea caerulea* (Fossen *et al*., 1999), alcoholic flower extract of *Nymphaea caerulea* (Agnihotri *et al*., 2008), ethanolic extract from the leaves of *Nymphaea odorata* (Zhang *et al*., 2003) and leaves of *Nymphaea lotus* (Elegami *et al*., 2003). Presence of rhamnoside, rhamnopyranoside, galactopyranoside, xylopyranoside, glucopyranoside attached with Quercetin were reported from the blue flowers of *Nymphaea caerulea* (Fossen *et al*., 1999), leaves of *Nymphaea odorata* (Zhang *et al*., 2003), methanolic extract of whole plant of *Nymphaea ampla* and *Nymphaea elegans* (Marquina *et al*., 2005), ethanolic flower extract of *Nymphaea caerulea* (Agnihotri *et al*., 2008).

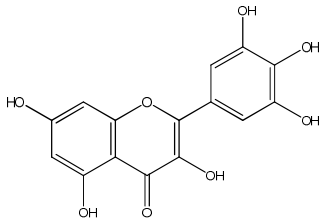
Fig. 1. Structures of phytoconstituents from the genus *Nymphaea.*



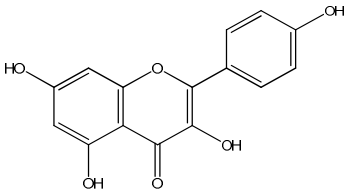
Nupharin and Aporphine Based compounds



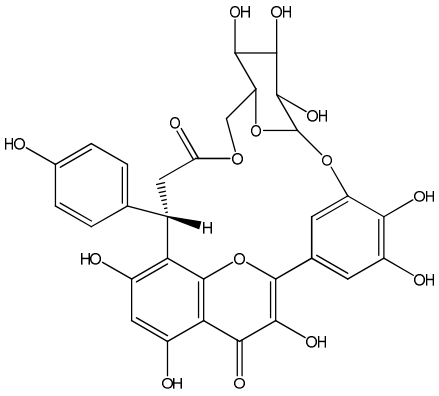
Delphinidin



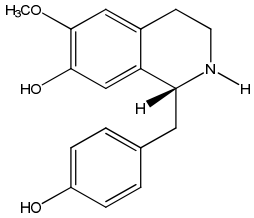
Myricetin



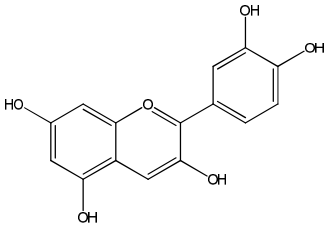
Kaempferol



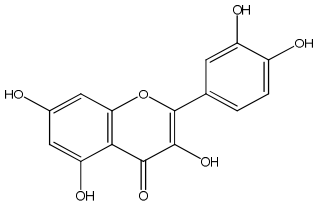
Nympholide A



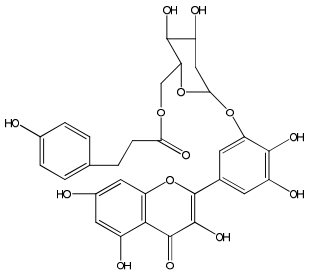
Nupharin and Nymphaeine



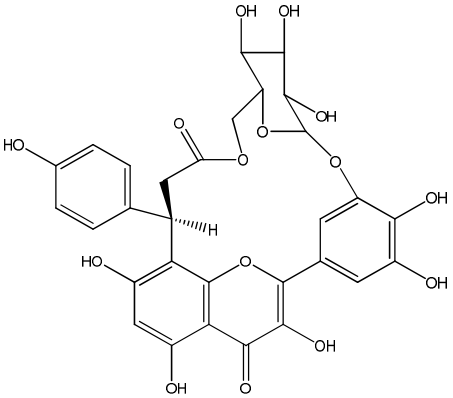
Cyanidin



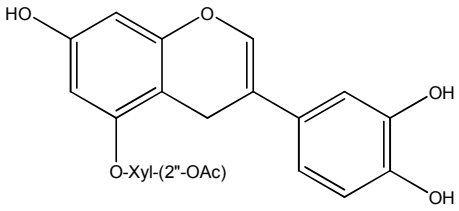
Quercetin



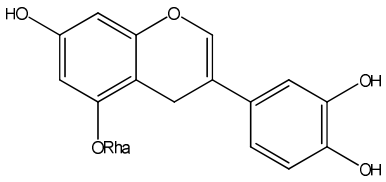
Myricetin – 3'-o-(6"-p-coumaroyl) glycoside



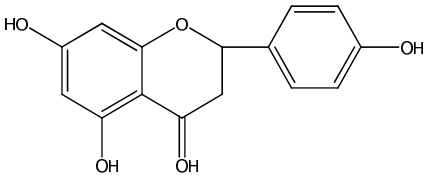
Nympholide B



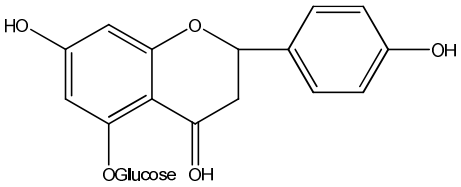
7, 3',4'-Trihydroxy 5-o-β-D-(2"-acetyl) xylopyranosylisoflavone



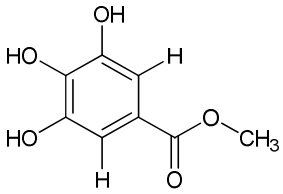
7, 3', 4'- Trihydroxy 5-o-α-L-rhamnopyranosylisoflavone



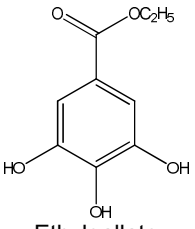
Naringenin



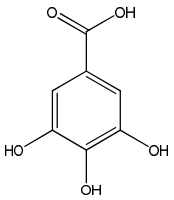
(S)-Naringenin 5-o-β-d-glucoside



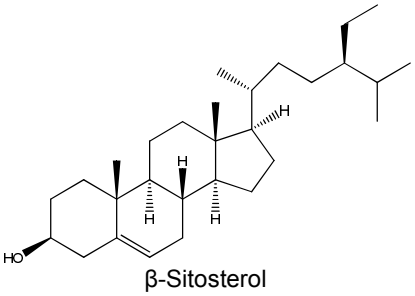
1, 2, 3, 4, 6 – Pentagalloyl glucose
Methyl gallate



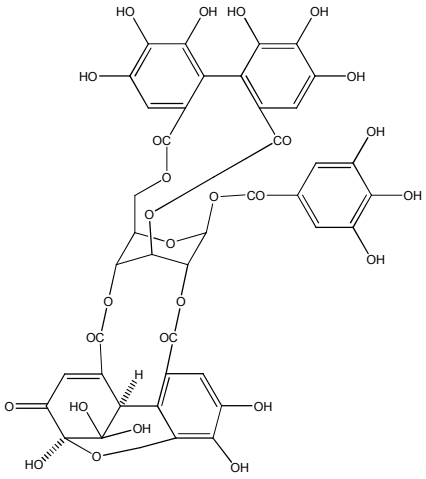
Ethylgallate



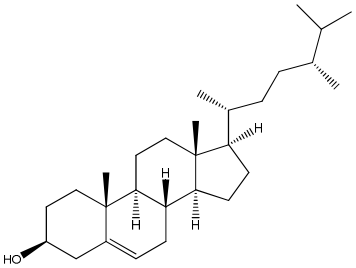
Gallic acid



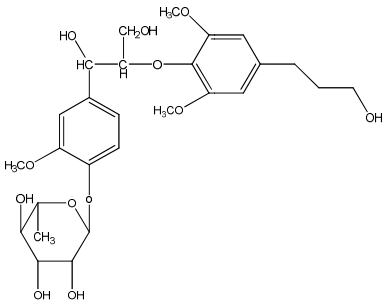
β-Sitosterol



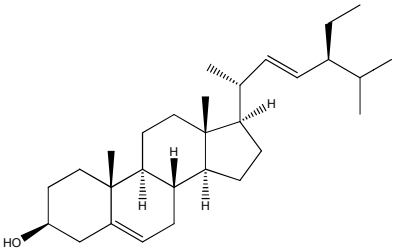
Gerannin



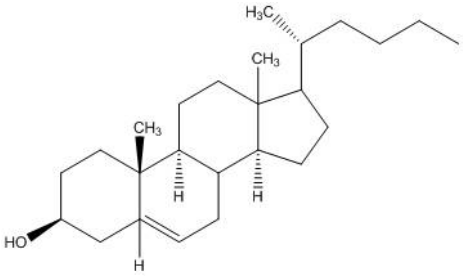
Campesterol



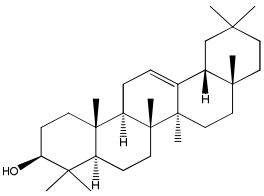
Nymphaeoside A



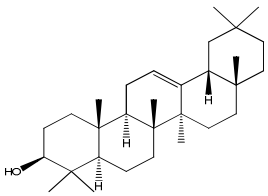
Stigmasterol



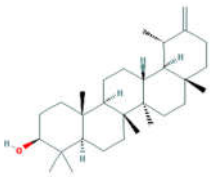
Nymphyol



Nymphasterol

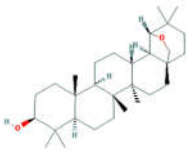


α & β – Amyrin

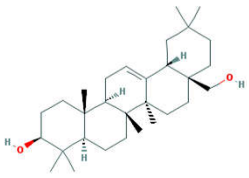


Taraxasterol

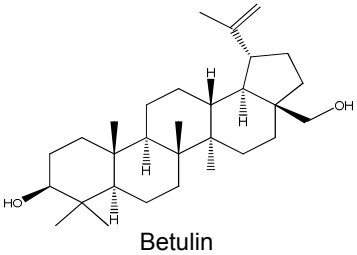
Friedlin



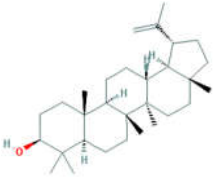
Allobetulin



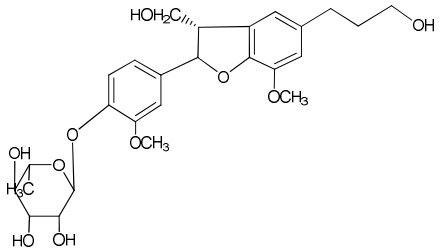
Erythrodiol



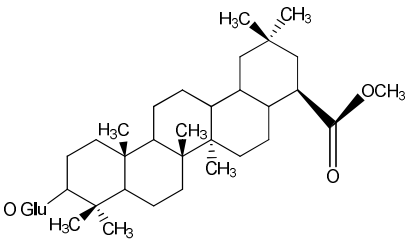
Betulin



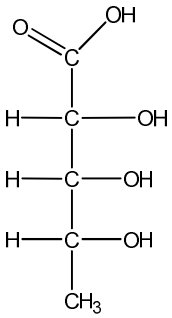
Lupeol



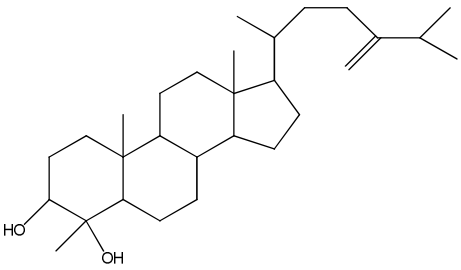
Icariside E_4



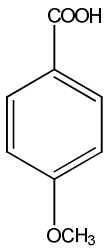
Methyl oleanolate – 3-o-β-D-glucopyranoside



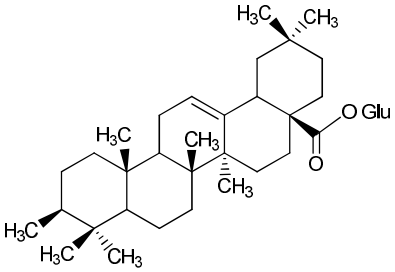
2S, 3S, 4S-trihydroxy pentanoic acid



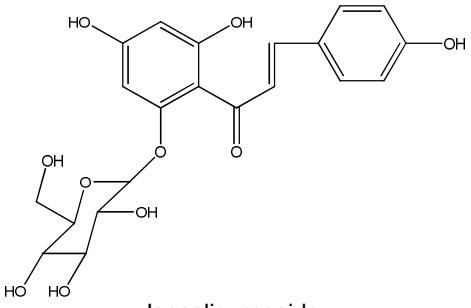
24-Methylene cholesterol palmitate



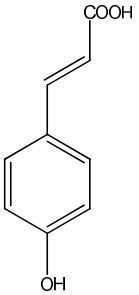
4-Methoxy benzoic acid



28-o-β-D-glucopyranosyloleanate



Isosalipurposide



4a-Methyl-5a-ergosta-7, 24 (28)-diene, 4β-diol
p-coumaric acid

Presence of rhamnoside and rhamnopyranoside (Afzelin) attached with Kaempferol were reported from the blue flowers of *Nymphaea caerulea* (Fossen *et al*., 1999), ethanolic extract from the leaves of *Nymphaea odorata* (Zhang *et al*., 2003), methanolic extract of whole plant of *Nymphaea pulchella* (Marquina *et al*., 2005), ethanolic flower extract of *Nymphaea caerulea* (Agnihotri *et al*., 2008). Macrocyclic flavonol glycosides such as Myricetin-3'-o-(6"-p-coumaroyl) glucoside, Nympholide A and B were reported from the methanolic leaf extract of *Nymphaea lotus* (Elegami *et al*., 2003). The glycosyl flavones such as 7, 3', 4'-trihydroxy-5-o-β-D-(2"-acetyl) xylopyranosyl-isoflavone reported from methanolic extract of whole plant of *Nymphaea ampla*and 7, 3', 4-trihydroxy-5-o-α-l-rhamno-pyranosyl-isoflavone reported from methanolic extract of whole plant of *Nymphaea pulchella* (Marquina *et al*., 2005).

Theflavonone Naringenin and flavonone glycoside (S)-Naringenin 5-o-β-d-glucoside were reported from the flowers of *Nymphaea caerulea* (Agnihotri *et al*., 2008). Presence of 1,2,3,4,6-pentagalloyl glucose is reported from methanolic extract of the leaves of *Nymphaea lotus* (Elegami *et al*., 2003), methyl gallate from the methanolic extract of whole plant of *Nymphaea ampla* (Marquina *et al*., 2005), gallic acidfrom the alcoholic extract from the flowers of *Nymphaea alba* (Joshi *et al*., 1974) and ethyl gallate and gallic acid from the flowers of *Nymphaea caerulea* (Agnihotri *et al*., 2008). Geraniin, an antimicrobial hydrolysable tannin against fish pathogenic bacteria is reported from the acetone leaves extract of *Nymphaea tetragonna* (Kurihara *et al*., 1993). β-Sitosterol is reported from the alcoholic flower extract from *Nymphaea alba* (Vidya Joshi *et al*., 1974). Campesterol, stigmasterol, β-Sitosterol and triterpenes β-Amyrin, Taraxasterol, Friedlin, Allobetulin, Erythrodiol, Lupeol Betulin were reported from the leaves, stems and roots of *Nymphaea odorata*. (Shirly and Chandler., 1984), β-Sitosterol, β-Sitosterol palmitate were reported from the flowers of *Nymphaea caerulea* (Agnihotri *et al*., 2008), Nymphyol is reported from *Nymphaea stellata* (Raja *et al*., 2010), Nymphasterol is reported from the seeds of *Nymphaea stellata* (Verma *et al*., 2011), β-Sitosterol and β-Sitosterol-3-o-β-D-glucopyranoside were reported from the methanolic extract of whole plant of *Nymphaea pulchella*, *Nymphaea gracillis* & *Nymphaea elegans* (Marquina *et al*., 2005). Nymphaeoside A and Icariside E_4 where reported from the ethanolic extract of the leaves of *Nymphaea odorata* (Zhang *et al*., 2003). Methyl oleanolate-3-O-β-D-glucopyranosideand 28-O-β-D-glucopyranosyl-oleanateis reported from *Nymphaea gracilis* (Marquina *et al*., 2005), 2S, 3S, 4S-trihydroxy pentanoic acid, isosalipurposide, 24-methylene cholesterol palmitate, 4a-methyl-5a-ergosta-7, 24 (28)-diene 3β, 4β-diol, p-coumaric acid and 4-methoxy benzoic acid from the flowers of *Nymphaea caerulea* (Agnihotri *et al*., 2008).

Pharmacological studies

Antidiabetic activity: Hydroethanolic extracts of *Nymphaea stellata* flowers is screened for antidiabetic activty in normal and Alloxan induced diabetic rats. The effect of oral administration of the hydro ethanolic extract for 30 d on the level of blood glucose, glycosylated hemoglobin, total cholesterol, triglycerides, phospholipids, low density lipoprotein, very low density lipo protein, high density lipoprotein, hexokinase, lactate dehydrogenase and glucose-6-phosphatase in normal and alloxan induced diabetic rats were evaluated. The hydro-ethanolic extract decreases the elevated blood glucose level, glycosylated hemoglobin, cholesterol, triglycerides, phopholipids, LDL, VLDL, hexokinase and it showed a significant increase in liver glycogen, insulin, glucose-6-phosphatase and HDL level. *Nymphaea stellata* flowers possess promising antidiabetic effect in diabetic rats (Rajagopal and Sasikala, 2008).

The ethanolic and aqueous flower extract of *Nymphaea pubescens* Willd is screened for antidiabetic activity in alloxan induced diabetic rats. There is significant reduction in blood glucose level in the diabetic rats and the percentage reductions were found to be 21.97% and 19.94% when administered with the dose of 400 mg/kg with ethanol and aqueous extracts (Karthiyayini *et al*., 2011). The ethanolic extracts of *Nymphaea pubescens* is screened for antidiabetic, hypolipidaemic and antioxidant activity in alloxan induced diabetic rats (Selvakumari and Shantha, 2010), screened for *in vitro* antidiabetic activity by *α-amylase* and *α-glucosidase* inhibition assay (Rajan *et al*., 2012), screened for antioxidant activity. The total phenolic and total flavonoid content of *Nymphaea pubescens* were estimated (Dalmeida and Mohan, 2012). Oral administration of Nymphayol isolated from *Nymphaea stellata* for 45 d to the experimental animals significantly lowered the blood glucose level and effectively increased the insulin content in diabetic rats. Nymphayol increased the number of β-cell mass enormously, Islet-like cell clusters in the islets of Langerhans were clearly observed based on histochemical and immunohisto-chemical studies (Subash *et al*., 2009). The methanolic extract of *Nymphaea nouchali* stem significantly and dose dependently reduced blood glucose concentrations in glucose loaded mice. The reduction in the blood glucose levels are 20.7, 36.9, 48.0 and 40.1% respectively when administered with the dose of 100, 200 and 400 mg/kg to the experimental animals. The standard group received with 10 mg/kg standard drug Glibenclamide showed 45.3% reduction. The antihyperglycemic effect is due to the presence of alkaloids, flavonoids, saponins and tannins (Mithila *et al*., 2015). Oral administration of *Nymphaea nouchali* extract showed significant restoration of blood glucose level, lipid profile, hepatic and renal markers (SGOT, SGPT, ALP, bilirubin and creatinine) to normal after 21 d of treatment. Histopathological studies of the heart and liver showed normal histological pattern in the normal and extract treated groups (Mabel and Francis, 2014).

Hepatoprotective activity: Nymphaea stellata is investigated for hepatoprotective activity against carbon tetra chloride induced hepatic damage. The oral administration of varying dosage to rats for 10 d afforded the good hepatoprotection against carbon tetrachloride induced elevation in serum marker enzymes, serum bilirubin, liver peroxidation and reduction in liver glutathione, liver glutathione peroxidase, glycogen, superoxide dismutase, catalase activity and glycogen content (Bhandarkar and khan, 2004). The ethanolic flower extract from *Nymphaea alba* is investigated for hepatoprotective activity by carbon tetra chloride and paracetamol induced hepatotoxicity in experimental rats. The ethanolic extract of *Nymphaea alba* (200 and 400 mg/kg) produced significant reduction in the wet liver weight and altered the serum enzymes SGOT, SGPT

and ALP, bilurubin and cholesterol levels to normal (Ashish and Pandurangan, 2016).

Hyperproliferative response and renal carcinogenesis: Nymphaea alba is investigated for its prophylactic effect against ferric nitrilo triacetate induced renal oxidative stress, hyperproliferative response and renal carcinogenesis in wistar rats. Treatment of rats orally with *Nymphaea alba* 100 and 200 mg/kg body weight resulted in significant decrease in glutamyl transpeptidase, lipid peroxidation, xanthine oxidase, hydrogen peroxide generation, blood urea nitrogen, serum creatinine, DNA synthesis and incidence of tumors. *Nymphaea alba* is a potent chemopreventive agent and suppress hyperproliferative response and renal carcinogenesis in wistar rats (Khan and Sultana, 2005).

Mutagenic activity: Nymphaea lotus is screened for toxicity and mutagenic activity. The ethanolic extract was screened for brine shrimp lethality tests, inhibition of telomerase activity and induction of chromosomal aberrations *in vivo* in rat lymphocytes (Sowemimo *et al*., 2007).

Antiproliferative activity: The ethanolic extract of various parts of *Nymphaea pubescens* such as leaves, fruits, flower, root and rhizome were screened for cytotoxic effect against human cervical carcinoma *Hela* cell lines and human breast carcinoma MCF7 cell lines. The ethanolic flower extract showed the most potent cytotoxic effect and the IC_{50} value is found to be 91.57 µg/mL against *Hela* cell lines and 99.67 µg/mL against MCF7 cell lines respectively (Selvakumari and Shantha, 2012).

Tumor inhibitory activity: The methanolic extract of *Nymphaea nouchali* roots at 200 mg/mL were screened for their inhibitory activity toward tumor promoter 12-o-hexadecanoyl phorbol-13-acetate induced Epstein-Barr virus activation in the Raji cells. The extract was inactive with zero inhibition rate (Raja *et al*., 2010).

Cholinergic activity: The alcoholic extract of the defatted fruits of *Nymphaea stellata* produced mild sedation and ataxia, potentiated hexobarbitone induced hypnosis in mice and also produced a sharp and transient hypotension blocked by pretreatment with atropine. If large doses were administered after atropinization, a rise in blood pressure and also a stimulant effect was observed on guinea pig ileum indicating the presence of unstable cholinergic priniciple (Raja *et al*., 2010).

Analgesic and Anti-inflammatory activity: The alcoholic extract of *Nymphaea stellata* had a significant analgesic activity byaconitine-induced writhing in mice and the antipyretic activity against carrageenin-induced rat paw edema. The anti-inflammatory activity exhibited was comparable to that of hydrocortisone (Raja *et al*., 2010).

The ethanolic extract of *Nymphaea alba* rhizome is investigated for analgesic activity by acetic acid induced pain model and formalin induced pain model method. The extract administered to the experimental animals at a dose of 600 mg/kg was found more potent activity (Anindya *et al*., 2012). The anti-inflammatory activity of *Nymphaea alba* ethanolic flower extract is investigated using acetic acid induced vascular permeability chronic models in swiss albino mice. Oral administration of ethanolic extract at the dose of 100 mg and 200 mg/kg b.w showed high significant dose independent activity compared with the standard drug diclofenac sodium (Jacob *et al*., 2013).

Antimicrobial activity: Flowers of *Nymphaea nouchali* were effective against *Pseudomonas aeruginosa*, *Bacillus cereus* and *Staphylococcus aureus*. *Nymphaea stellata* also exhibited broad spectrum of activity against phytopathogenic bacteria. The ethanolic extract of *Nymphaea stellata* leaves has shown considerable antibacterial activity against *E. coli* (Raja *et al*., 2010). The LD_{50} value of 50% ethanolic extract of *Nymphaea stellata* was found to be 681 mg/kg in albino mice. *Nymphaea stellata* was found to be inactive as an antibacterial, antifungal, antiprotozoal, antiviral, diuretic with no effect on the cardiovascular system and central nervous system (Raja *et al*., 2010).

Antinociceptive activity: Methanolic extract of *Nymphaea nouchali* stem is screened for antinociceptive activity by acetic acid induced pain model in experimental mice. The extracts at dosed of 50, 100, 200 and 400 mg/kg significantly and dose dependently reduced acetic acid induced abdominal constrictions in mice by 29.6, 37.0, 44.4 and 51.9% respectively. The experimental animals administered with standard drug aspirin showed 51.9% reduction (Saha *et al*., 2015).

Docking studies: A lead molecule Guggultetrol isolated from *Nymphaea pubescens* docked with the targeted enzyme protein Glucokinase involved in the treatment of type II diabetes mellitus. Guggultetrol was found to bind at active site of Glucokinase with lowest binding energy and RMSD value to be -9.45 cal/mol and 2.0Å respectively. The ligand binding affinity towards the targeted protein residues are Thr-168, Glu-290, Glu-51, Ser-411, Gly-410, Asn-254, Thr-206,Arg-155 and Asp-205. From the *In silico* studies, it is identified that Guggultetrol inhibit the targeted enzyme Glucokinase (Kiran, 2013).

Antioxidant activity: The ethanol and chloroform extracts of *Nymphaea nouchali* leaves were investigated for their antioxidant property. Antioxidant property was evaluated by using total antioxidant capacity, DPPH (1,1-diphenyl-2-picrylhydrazyl) scavenging capacity, total phenol and flavonoid contents. DPPH assay free radical scavenging activity of the extracts was evaluated comparing with ascorbic acid at 517 nm.

The IC_{50} of ethanolic extract of *Nymphaea nouchali* is 10.102±0.23 µg/mL and chloroform extract of *Nymphaea nouchali* is 13.11±0.11 µg/mL where as the IC_{50} of ascorbic acid was 19.89± 0.22 µg/mL. Phenolic content was measured by Folin-Ciocalteu assay and is expressed as Gallic acid equivalents (GAE). The content of phenolic compound in the extracts correlates with the antioxidant activity, being higher in ethanol extract of *Nymphaea nouchali* (6.53±0.26 mg/g GAE) and lower in chloroform extract of *Nymphaea nouchali* (5.55±0.06 mg/g GAE) and flavonoid contents were found 4.58±0.19 mg/g quercetin equivalent for chloroform extract and 5.99±0.33 mg/g quercetin equivalent for ethanol extract respectively. But both of the extracts contain almost similar amount of total antioxidant capacity having 2.75±0.12 mg/g ascorbic acid equivalent (AAE) for ethanolic extract and 2.69±0.09 mg/g AAE for chloroformic extract. Data of this study reveals that the medicinal plant *Nymphaea nouchali* is rich source of antioxidants (Noor *et al*., 2013). The ethanolic extract of *Nymphaea alba* rhizome is investigated for antioxidant potential by DPPH, nitric oxide and superoxide anion radical scavenging activity. The IC_{50} value for DPPH, NO and superoxide anion radical scavenging activity were 63.9, 49.21 and 79.56 respectively. The antioxidant activity observed may be due to the presence of tannins and phenolic compounds (Anindya *et al*., 2012).

Antiurolithiatic activity: The antiurolithiatic activity was screened for ethanolic extract of *Nymphaea alha* by inducing urolithiasis into experimental animals by inserting zinc disc in the urinary bladder. The reduction in the weight of the stones was used to assess the curative regimen. The ethanolic extract of dried leaves of *Nymphaea alba* showed the prophylactic and curative property in the experimental animals. There is a significant reduction in the weight of bladder stones compared to the control groups (Bhaskar *et al*., 2012).

Uterotonic activity: Uterotonic properties of ethanolic extract of *Nymphaea alba* rhizome on rat uterus in the presence of standard antagonists like salbutamol and atropine and uterine stimulant like oxytocin were examined. It was investigated on rat uterus pre-treated with 1 mg/kg stilboesterol for 24 h. The effects of oxytocin-a uterine contraction agonist, antagonists like atropine (1-2 mg) and salbutamol (2 µg) on the uterine contractile effect of the extract were investigated. The ethanol extract of *N. alba* produced a dose related increase in the force of uterine contraction similar to Oxytocin. The drug Oxytocin was observed to potentiate the uterine contractile activity of the extract while pre-treating the tissue with either atropine or salbutamol before administering the extract showed the inhibitory effects of the drugs on the activity of the extract. The inhibition of contractile effect of the *N. alba* extract showed by atropine and salbutamol suggests the probable stimulation of the muscarinic and adrenergic receptors of the uterus by the extract. These findings justify the traditional use of the plant for its uterotonic properties (Anindya *et al*., 2014).

Phytosome formulation: Phytosome was formulated from the methanolic extract of *Nymphaea nouchali*. The phytosome is formulated by reacting phosphotidyl ethanolamine in tetra hydro furan with the methanolic extract of *Nymphaea nouchali* in dioxane: methanol (7:3). Different molar ratios (1:1, 1:2, 1:4, 1:6, 1:8 and 1:10) were employed using solvent evaporation technique. *In vitro* appraisal encompassed differential colorimetry, infrared spectroscopy, particle size, drug content, diffusion and stability studies. The results revealed that the optimized phytosomal carriers, PE(Nn/Td) exhibited the mean particle size of 268 nm and good *in vitro* stability in the ratio of 1:8. It also exhibited significant enhancement in diffusion rate compared to crude drug mixture and standard Levimasole. Thus, the phytosomal carrier with 89% of entrapped drug could be successfully tailored for Nn/Td with improved *in vitro* release characteristics which is promising for increasing drug delivery and decreasing the effect of exogenous factors (Sumathi and Sethamarai, 2015).

Conclusion

The perception on the genus of *Nymphaea* showed the presence of wide range of primary and secondary phytomolecules. The unique and novel phytomolecules present in the genus *Nymphaea* are the key to unlock the folklore claims of the various species in *Nymphaea*. The scientific research today focuses on the discovery of novel and unique molecules and on revealing unknown targets of lead molecule in nature. New and improved research protocols concerning the selection of plant drug, based on ethnomedical information or folklore claims, pharmacognostic standardization, chromatographic studies, bio-assay guided fractionation, hyphenated techniques, isolation procedures, structural elucidation using spectroscopic studies, *in vitro* and *in vivo* pharmacological bioassays, molecular screening, toxicity studies, screening of isolated compounds by computational molecular docking studies, *in vivo* molecular screening including the blotting techniques and clinical trials of the isolated phytomolecules provides the outstanding contribution to the future drug discovery. Hence, the future scientific research work on the fascinating aquatic plant species belong to the genus *Nymphaea* has to be taken in consideration for validating the folklore claims based on the above mentioned advancement in revealing the novel lead molecules for future drug discovery from the food source *Nymphaea*.

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