The Phytochemistry and Antioxidant Activity of the *Nelumbo nucifera* (Lotus) Plant: A Review

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Abstract

Plant extracts are used in a range of products, including fairness creams, fragrances, body lotions, and other formulations. Herbal plants comprise alkaloids, glycosides, terpenes, steroids, flavonoids, tannins, and other secondary metabolites. Polyphenols have antioxidant properties, which have an assortment of health benefits. Medicinal properties can be found in almost all parts of the *Nelumbo nucifera* (Lotus) plant. Phytochemicals, as well as secondary metabolites like phenols, flavonoids, tannins, alkaloids, sterols, terpenoids, cardiac glycosides, coumarins, and quinones, are found in the lotus extracts. Methanol and Butanol extracts of *N. nucifera* are observed to have scavenging activities on free radicals and hydroxyl radicals, as well as the metal-binding ability and reducing power. Natural antioxidant potential has been observed in the leaf, stamens, and seed extracts of *N. nucifera*. The antioxidant activities of various organic and aqueous extracts of *N. nucifera* have been demonstrated in pharmacological studies. Antioxidant activity and total phenolic content may differ depending on geographical location and growth conditions of the plant. Further research into the fine structures of lotus active ingredients, as well as structure-activity relationship mechanisms, are required in the future to overcome the challenges of different extraction methods and in the studies of therapeutic efficacy of the *Nelumbo nucifera* plant.

Keywords: *Nelumbo nucifera*, Phytochemistry, Antioxidant property, DPPH, Lotus extract, free radicals

Introduction

Plant components and extracts have long been employed in the pharmaceutical, cosmetic, and food industries. There are minimal or no detrimental side effects when plants as well as plant extracts are utilized in applications. Fairness creams, fragrances, body lotions, and other formulations containing plant extracts are popular[1,2]. Alkaloids, glycosides, terpenes, steroids, flavonoids, tannins, and other secondary metabolites are found in herbal plants. Polyphenols have antioxidant properties, which have a variety of health benefits[3].

Since ancient times, many of these herbal products and spices have served as useful medicinal sources for humans[5]. Metabolism as well as illnesses produce significant amounts of free radicals and Reactive Oxygen Species (ROS) which may lead to oxidative stress. Antioxidants are important to restore the oxidant balance in the body in such circumstances. Natural antioxidants are preferred due to their minimal risks and side effects. Various in vitro and in vivo methods have been used to estimate the antioxidant properties of various parts of the lotus until now. However, no single metric is thought to be sufficient in determining total antioxidant capacity. This review aims to explore some important aspects of the antioxidant properties in different parts of the *Nelumbo nucifera* plant.

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Botanical description of the Nelumbo nucifera plant

Nelumbo nucifera belongs to the Nymphaeaceae family of plants. It belongs to the order Proteales and genus Nelumbo. Indian lotus, water lily, and Chinese lily are some of the names by which this plant is recognized in various geographical locations[4,5]. Lotus is a perennial aquatic plant with a fleshy yellow rhizome, an elongated creeping stem, nodal roots, green fruits, and large leaves.

Lotus flowers come in two varieties: white flowers and pink or reddish-pink blossoms (Figure 1).

Figure 1: The *Nelumbo nucifera* flower[6]

Flowers are sweet scented, hermaphrodites, and solitary. The aggregate fruit of this plant has a tough, brownish, longitudinally striated pericarp, and a single seed contained within the fruit. The seeds are released by bending the pod down to the water. The leaves of this plant float on the water's surface, while the roots are anchored in the pond or river bed. Petioles are long, rough and prickled. The roots float in aquatic systems due to the presence of numerous air pockets that run the length of the tuber. Australia, China, India, Sri Lanka, Iran, and Japan are all home to *Nelumbo nucifera*. Lotus has evolved to thrive in moist and humid conditions such as flood plains and slow-flowing rivers. Medicinal properties can be found in almost all parts of the plant. The flower, seed, rhizome, and leaves are used to treat conditions such as smallpox, diarrhoea, cough, fever, and cholera. Ayurveda also uses these plant elements to treat nausea, leprosy, and skin disorders. It is commonly used to diagnose conditions like tissue inflammation, cancer, and skin disorders. Alkaloids, steroids, flavonoids, glycosides, and polyphenols are among the pharmacologically active phytoconstituents credited with these abilities[3–5].

Phytochemistry and constituents of Nelumbo nucifera.

Primary metabolites like carbohydrates, proteins, and lipids are found in *Nelumbo nucifera* extracts, as well as secondary metabolites like phenols, flavonoids, tannins, alkaloids, sterols, terpenoids, cardiac glycosides, coumarins, and quinones (Figure 2)[4,5].

Nuciferine, pronuciferine, lotusine, rutin, hyperin, and demethylcoclaurine are phytochemicals found in embryos. Linalool, luteolineglucoside, dehydrnonaine, anonaine, armepavine, kaempferol-3-O—D-gluceronide, asimiloine, demethylco-claurine, and lirinidine are among the compounds found in the stamen. Quercetin, luteolin, luteolinglucoside, kaempferol, kaempferol-3-O-glucocide and isoquercitrin are present in the flower. The leaves contain roemerine, nuciferine, nornuciferine, armepavine, pronuciferine, N-nornuciferine, anonaine, liriodenine, quercetin, tartaric acid, gluconic acid, acetic acid, malic acid, ginnol, nonadecane, and succinic acid whereas the seeds contain dauricine, nuciferine, roemerine, lotusine, armepavine, liensinine, neferine, and isoliensinine[4,7].

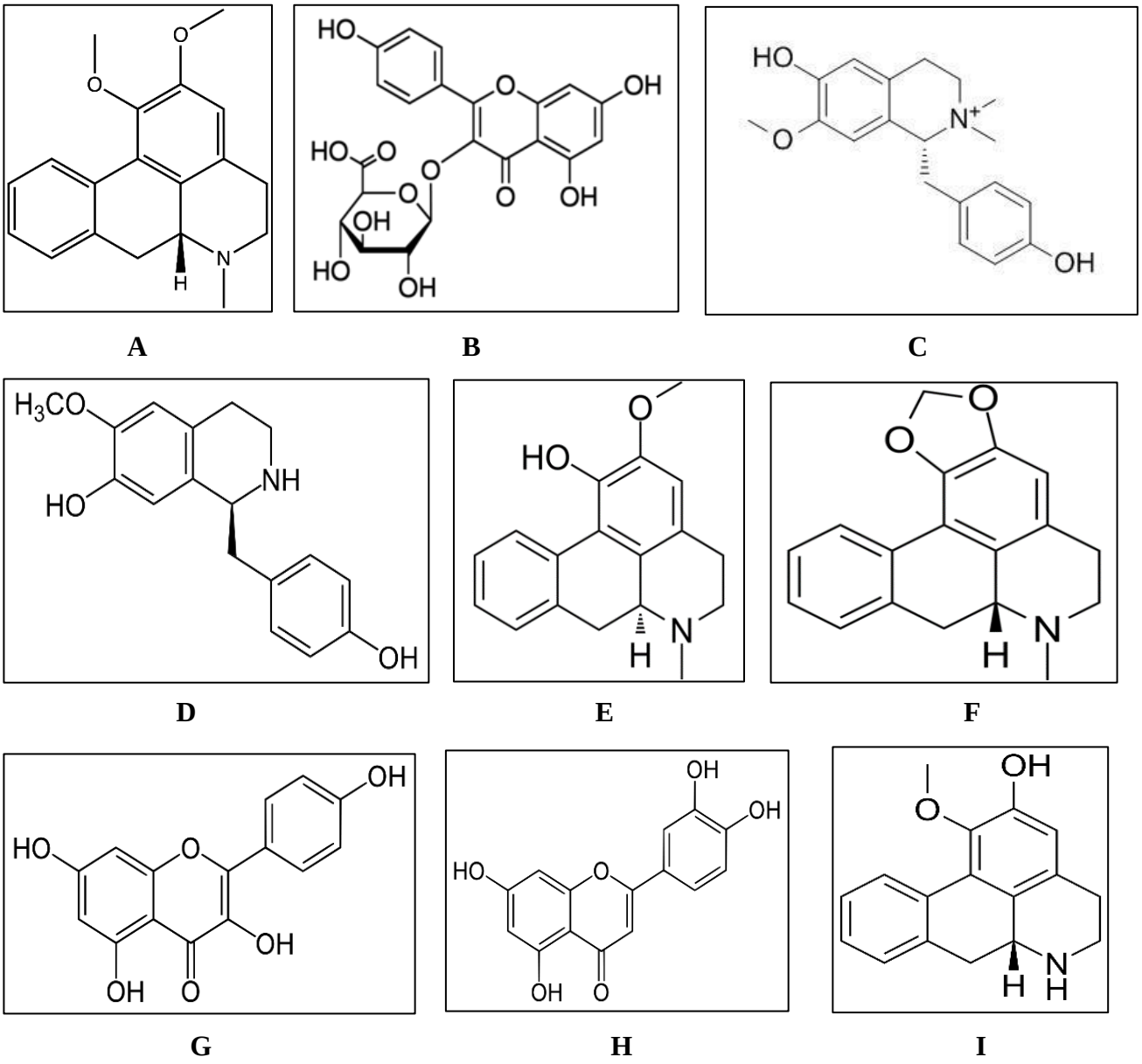

Figure 2: Chemical constituents present in *Nelumbo nucifera* (A: Nuciferine, B: Lotusine, C: Demethylcoclaurine, D: Kaempferol-3-O-*β*-D-glucuronide, E: Lirinidine, F: Roemerine, G: Kaempferol, H: Luteolin, I: Asimilobine)[8]

Antioxidant activity of Nelumbo nucifera

Owing to various metabolic activities or illnesses, free radicals, or reactive oxygen species (ROS) are produced in the cells of an organism. To prevent or neutralize the free radicals produced by these processes, exogenous and endogenous defensive mechanisms exist. Catalase, superoxide dismutase, and glutathione peroxidase are examples of endogenous sources, while vitamin C and E, as well as beta carotene, are examples of exogenous sources. Antioxidants are important to maintain the body's natural oxidant balance.[9]

Natural antioxidants are of particular interest to researchers due to the potentially harmful effects of synthetic antioxidants. Secondary metabolites include carotenoids, flavonoids, cinnamic acid, folic acid, ascorbic acid, tocopherols, and other phytochemical antioxidants[10].

Various in vitro and in vivo methods have been used to estimate the antioxidant properties of various parts of the lotus until now. However, no single metric is thought to be sufficient in determining total antioxidant capacity[11].

Antioxidant activity of N. nucifera leaf

According to in vitro assays, the methanol extracts of *N. nucifera* are observed to have free radical scavenging activity, metal-binding ability and reducing power, which may explain in part the mechanism behind the ability of the *N. nucifera* extract to protect cells from oxidative damage. Furthermore, the extract has concentration-dependent antioxidant properties against hemoglobin-induced linoleic acid peroxidation and Fenton reaction-mediated plasmid DNA oxidation[12]. Rutin, catechin, sinapic acid, chlorogenic acid, syringic acid, and quercetin, as well as a high total phenolic and flavonoid content, are found in the phenolic rich ethyl acetate fraction (EAF) from lotus leaves. It inhibits polyunsaturated fatty acid lipid peroxidation in a linoleic acid emulsion and shows strong reducing power against DPPH and ABTS cation radicals. It has also been shown to protect DNA from hydroxyl radical damage, as evidenced by the conversion of supercoiled pBR322 plasmid DNA to the open circular form. EAF also inhibits intracellular ROS formation and membrane lipid peroxidation in cultured hepatocytes, making it a cytoprotective agent against oxidative stress. Furthermore, EAF treatment significantly restored glutathione depletion caused by oxidative stress[13].

Methanol and Butanol extracts are found to have a higher capacity to scavenge DPPH radicals, delay LDL oxidation, and contain more antioxidative compounds. Quercetin and its glycosides inhibit LDL oxidation effectively, whereas myricetin-3-O-glucopyranoside has a stronger DPPH scavenging activity than the other flavonoids. These findings suggest that flavonoids play a role in the antioxidant capacity of lotus leaves[14].

Antioxidant activity of N. nucifera stamens

Stamens, which are necessary for reproductive functions, are also promising new sources of antioxidants. The ability of *Nelumbo nucifera* stamens to scavenge stable 1,1-diphenyl-2-picrylhydrazyl (DPPH) free radicals and inhibit total ROS generation in kidney homogenates using 2',7'-dichlorodihydrofluorescein diacetate (DCHF-DA) and scavenge authentic peroxynitrites (ONOO-) has been investigated where EtOAc soluble fraction showed strong antioxidant activity after fractionation with several organic solvents, including dichloromethane (CH2CI2), ethyl acetate (EtOAc), and n-butanol (n-BuOH). Kaempferol had the highest antioxidant activity of the flavonoids isolated from the stamens. In the DPPH and ONOO- tests, the compounds kaempferol 3-O-13-D-glucuronopyranosyl methylester and kaempferol 3-O-13-D-glucuronopyranoside showed scavenging activity, whereas kaempferol 3-O-I-D-glucopyranoside and kaempferol 3-O-13-D-galactopyranoside were only active in the ONOO- test. Compound 13-sitosterol glucopyranoside, on the other hand, lacked antioxidant properties[15]. Other than flavonoids, the compound isorhamnetin isolated from *N. nucifera* stamens also show marked antioxidant properties in the DPPH and ONOO- assays[16].

Antioxidant activity of N. nucifera seeds

Apart from the alkaloids found in lotus seed embryos, flavonoids have received a lot of attention due to their potential health benefits in the treatment of diseases such as neurodegenerative diseases, type 2 diabetes, and cardiovascular diseases[17].

The flavonoid C-glycosides in lotus seed embryos were first discovered using tandem mass spectrometry and high-performance liquid chromatography (HPLC-MS)[18].

The antioxidant properties of lotus seed extracts have been investigated, as well as their effect on DNA damage in human lymphocytes. The findings revealed that boiling water extracts of lotus seeds (WELS) had higher antioxidant activity and extract

yields than other organic solvents. On ferrous ions, the WELS showed significant chelating binding and strong interaction with hydrogen peroxide. The antioxidant activity of WELS is thought to be due to phenolic acids such as caffeic acid, chlorogenic acid, p-hydroxybenzoic acid, gallic acid, and large amounts of phenolic compounds found in WELS. In human lymphocytes, the WELS revealed no changes in lipid peroxidation or DNA damage, regardless of whether hydrogen peroxide was used to induce them[19].

In vivo and *in vitro* studies on the antioxidant activity of a hydroalcoholic extract of *Nelumbo nucifera* seeds (HANN) confirm that it has strong free radical scavenging activity, as evidenced by low IC50 values in both the DPPH and nitric oxide methods. The values were discovered to be lower than the rutin standard. When Wistar rats were given HANN at 100 and 200 mg/kg body weight for four days before carbon tetrachloride (CCl4) treatment, there was a significant dose-dependent increase in superoxide dismutase (SOD) and catalase, as well as a significant decrease in thiobarbituric acid reactive substances (TBARS) in both the liver and kidney, when compared to CCl4-treated controls. The changes seen at 100 mg/kg bodyweight treatment were comparable to those seen at 50 mg/kg treatment with standard Vitamin E. The findings support HANN's antioxidant properties[20].

Comparative antioxidant properties of different parts of Nelumbo nucifera

On testing, ten different parts of the lotus and comparing in vitro for antioxidant activity, it has been observed that the receptacle not only had the highest phenolic, flavonoid, and proanthocyanidin content of the ten lotus extracts, but its DPPH and ABTS radical scavenging activities, reducing power, and total antioxidant activity was also comparable to, if not better than, the butylated hydroxytoluene (BHT) control. The metal chelating activity of all ten lotus extracts was significantly higher than that of BHT. Nonetheless, the ability of all ten lotus extracts to scavenge hydroxyl radicals was significantly lower than that of the ascorbic acid control. In contrast to their ability to chelate metals, the phenolic compounds in the ten lotus extracts are most likely responsible for their DPPH and ABTS radical scavenging abilities[21].

Through free radical scavenging activity, total phenolic and flavonoid content, and concentration of several specific flavonoids and alkaloids in the ethanol extracts of lotus seeds and rhizomes, the variations in antioxidant activity and concentration of functional components in the ethanol extracts of lotus seeds and rhizomes based on the growing region and dryness were investigated. Antioxidant activity and total phenolic content differed significantly depending on the growing region and dryness. The ethanol extracts of lotus seeds from Vietnam (Ho Chi Minh City), raw rhizomes from Korea (Siheung), and dried rhizomes from Japan (Nigata) had the highest specific flavonoid content, according to high-performance liquid chromatography analysis. The highest specific alkaloid content was found in ethanol extracts of seeds from China (Hubei), raw rhizomes from Japan (Nigata), and dried rhizomes from Korea (Siheung). In this study, astragalin, rutin, isoquercetin, nuciferine, dauricine, isoliensinine, and neferine were discovered for the first time in lotus rhizomes[22].

Discussion

The antioxidant activities of various organic and aqueous extracts of *N. nucifera* have been demonstrated in pharmacological studies. Researchers have made progress in recent years in characterizing the biological activities of lotus plant components, identifying some active components, and elucidating the mechanism underlying the antioxidant effects.

However, because of the high nutritional value and multiple active ingredients found in lotus, there is still a lot of room for research and development, as evidenced by several factors: The extraction, separation, and purification of lotus nutrients and bioactive components are still incomplete, with the crude extract still containing most of the components. To develop more effective extraction

methods in the future, a variety of separation methods and coordination optimization strategies for different components should be implemented. Similarly, the therapeutic efficacy of active ingredients from the lotus plant is still unknown; the mechanism has not been thoroughly investigated, and most studies have focused on solvent extraction. Separation, purification, and structure determination are difficult to achieve due to a lack of systematic research. As a result, further research into the fine structures of lotus active ingredients, as well as structure-activity relationship mechanisms, will be required in the future to overcome the challenges; traditional medicine studies have described many functions for the lotus plant; however, current research focuses on only a few fields. As a result, all the benefits of this plant parts are still purely empirical, with little or no scientific backing; future research should broaden the scope of lotus seed application and expand its biological and pharmacological properties. People are paying more attention to their health as their living standards rise. Consumers will increasingly recognize and prefer natural products as nutritious and edible efficacious drugs.

Conclusion

Lotus is widely used in pharmaceuticals and health care products. The antioxidant potential of different parts of the *N. nucifera* plant could be exploited for therapeutic applications. Deeper research and development of new functional foods derived from the lotus plant will broaden the nutrition characteristics and physiological activities for a deeper processing pathway, resulting in significant economic and social benefits, as well as further exploitation in human health improvement.

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