Lotus (*Nelumbo nucifera* Gaertn)

2

Anu Pandita and Deepu Pandita

Abstract

Nelumbo nucifera Gaertn ($2n = 16$) (Nelumbonaceae), also known as the Sacred Lotus is an imperative perennial plant of aquatic habitat renowned for its prominent, beautiful, and magnificent flowers with diverse colors and owning nutritional and medicinal significance. Lotus of Asian countries are in shades of pink to pure white. Many bioactive chemical constituents mainly alkaloids, terpenoids, flavonoids, and phenolics have been identified in lotus. The medicinal principles relating to phytochemical and pharmacological activities mainly include antioxidant potential. In recent times, attention has mounted significantly in finding antioxidants from natural sources for utilization in foods or medicines. Because of the appraisal of antioxidant activity of plants as medicine, *Nelumbo nucifera* Gaertn which is very significant against damage triggered by the free radicals within a cell and reactive oxygen species (ROS) in a living being was explored for the antioxidant prospective of flowers, receptacles, leaves, seeds, and rhizomes. This chapter aims at understanding the antioxidant properties of different plant parts (leaves, flowers, receptacle, seeds, and rhizomes) of *Nelumbo nucifera* Gaertn, phytochemistry of its various bioactive compounds over and above alkaloids, flavonoids, glycosides, triterpenoids, etc., and the benefits derived from these phytoconstituents.

Keywords

Lotus Stem · Antioxidant activity · Reactive oxygen species · Pharmacological activity · Phytochemistry

A. Pandita
Vatsalya Clinic, New Delhi, India

D. Pandita (✉)
Government Department of School Education, Jammu, Jammu and Kashmir, India

G. A. Nayik, A. Gull (eds.), *Antioxidants in Vegetables and Nuts - Properties and Health Benefits*, https://doi.org/10.1007/978-981-15-7470-2_2

2.1 Introduction

Botanical Names
Nelumbo nucifera Gaertn
Nymphaea nelumbo Linn

Common Names
English: Lotus, Oriental Lotus, Bean of India, Hindu Lotus, Sacred Lotus, East Indian Lotus, Egyptian Bean, Sacred Water Lily, Sacred Water Lotus, Baladi Bean, Lotus Bean, Water Lotus, Indian Lotus, Egyptian Lotus, Chinese Water Lily
Hindi: Padam, Kamala, Kamal, Lalkamal, Kanwal, Ambuj, Kamal-Kakri

Nelumbo nucifera Gaertn (Sacred Lotus; $2n = 16$) is a significant economic and medicinal aquatic plant, which has irreplaceable cultural and religious importance for Buddhists and Hindus and belongs to a small plant family of Nelumbonaceae that is currently kept in the mono-generic Nymphaeaceae family (Duke et al. 2002; Wang and Zhang 2005), with a solitary genus Nelumbo, which further contains two species namely, Asian Lotus/Indian lotus or *Nelumbo nucifera* Gaertn (found throughout Asia in China, India, Australia, and Russia) and American Lotus/Water chinquapin or *Nelumbo lutea* Pers. (Eastern and Southern North America) (Mukherjee et al. 1996a, b; Williamson and Schneider 1993; Sayre 2004).

The fossil records disclose that 15 million years ago there were eight *Nelumbo nucifera Gaertn* species at global level (Wang and Zhang 2005; You 1998). In Asia, the lotus is under cultivation for more than 7000 years for its edible seeds, leaves, rhizomes, and beautiful flowers (Yang et al. 2012; Kubo et al. 2009; Shen-Miller 2002; Ming et al. 2013). The lotus seeds with extraordinary longevity remain viable for 1300 years and lotus rhizomes stay vigorous for above 50 years and shows remarkable property of water repellency, well known as the Lotus Effect because of nanoscopic narrowly packaged distensions of its self-cleaning surface of leaf (Shen-Miller et al. 2002; Shen-Miller 2002). The parts of lotus plant like flowers, androecium, pollens, rhizomes, stems, and leaves are both used as food/vegetables and a part of indigenous system of medicine in China as well as India (La Cour et al. 1995; Anonymous 1992; Mukherjee et al. 2009; Sridhar and Bhat 2007). The different parts of Lotus like buds, leaves, roots, stalks, rhizomes, flowers, and fruits have been employed as plant-based drugs for cure against diseases of hypertension, cancers, diarrheal problems, cardiovascular issues, depression, and insomnia (Shen-Miller et al. 2002; Duke et al. 2002). Antioxidant potential of lotus plant parts, for example, leaves (Wu et al. 2003), roots (Jung et al. 2011; Ham et al. 2017), stamens (Jung et al. 2003), and lotus rhizomes (Cho et al. 2003; Hu and Skibsted 2002) is well recognized. Leaves of lotus plant have diverse antioxidant chemicals like ascorbic acid, phenolic compounds, carotenoid compounds, flavonoid compounds, and tocopherol compounds (Choe et al. 2011).

Nelumbo nucifera Gaertn has various vernacular and botanical names. Indian *Nelumbo nucifera* Gaertn is recognized as the *Padma* and/or *Kamala* which has two plant varieties, commonly called the *Pundarika* or *Sveta Kamala* (white lotus variety); and the *Rakta Kamala* (pink or reddish pink lotus variety) (Chopra 1958). All the parts of lotus plant have a distinctive name and almost all the parts have medicinal value, providing one or more drugs (Raghunath and Mitra 2005). The whole lotus plant along with the flower is well known as *Padmini*, the rhizomes of lotus as *Kamalkand* (Nadru in Kashmiri), the leaves of lotus as *Sambartikai*, the peduncle of lotus as *Mrinal* or *Visa*, the stamens of lotus as *Kirijalika*, the receptacle of lotus as *Padma Makaranda* or *Padma-Madhu*, Padmakosa, seeds of lotus as *Karnika* or *Padmaksya* (Pambuch in Kashmiri), and honey of lotus flowers is known as *Makaranda* or *Padmamadhu* (Anonymous 1982). Ming et al. (2013) sequenced the lotus genome of the Chinese traditional variety with estimated 929 Mbp genome size. A lotus root which is a popular vegetable known as Nadru in Kashmiri has antianxiety, antifungal and anti-inflammatory activities (Du et al. 2010).

2.1.1 Origin and History

Lotus was in existence since 135 million years in the aquatic environment of Northern Hemisphere. This plant was bestowed with honor in history by countries like India, China, and Egypt (Karki et al. 2012, 2013; Harer 1985), wherein flower of lotus can be appreciated in their traditional art, culture, and religion. Lotus is admired in Australia Pacific, China, India, Korea, and Japan (Harer 1985; Anonymous 1992). *Nymphaea caerulea*, commonly known as the Sacred Blue Lotus, showed distribution sideways the banks of River Nile (Harer 1985; Anonymous 1966) along with lotus. Egyptians, Hindus, and Buddhists worship lotus. Egyptians worshipped the flowers, fruits, and sepals of lotus plant. After Egypt, lotus was transferred to region of Assyria and extensively planted throughout Indian, Persian, and Chinese regions. Lotus is common in Australian, Chinese, Indian, Iranian, and Japanese regions. From China, lotus was introduced to Japanese region and subjected to cultivation for over 1000 years. In China, lotus is grown as a crop with industrial value on above 40,000 hectares of land. In India, lotus is pervasive, and established in Himalayan lakes as well (Sridhar and Bhat 2007). Lotus is the “National Flower of India.” It is sacred and symbol of purity and sanctity. The garlands made from the white or mainly pink flowers are used for the decoration and worship of Goddess Lakshmi as a “symbol of wealth” in temples (Mehra et al. 1975). Lotus was under cultivation in the Far East since 5000–7000 years (Wong 1987); by way of proof of cultivation of lotus plant from >3000 years for utilization as food, drugs, and in events of cultural and religious significance (Shen-Miller 2002). Sir Joseph Banks (1787) initiated horticulture of lotus plant in Western Europe as stove-house water lily. Today, lotus plant is prevalent virtually ubiquitously in plant herbal and botanical garden collections.

2.1.2 Distribution and Production (India, World)

Nelumbo nucifera Gaertn – the lotus is native to China, Japan, and India. The natural distribution of Lotus extends from Japan to northeast Australia and across the Caspian Sea. Lotus is extensively dispersed throughout the Caspian Sea to the Asian zone. Lotus is widespread in a range of countries like North Australia, China, Iran, Korea, and Malaysia (Lim 2016). Guo (2009) put on records that *Nelumbo* is extensively cultivated throughout Indian continent because of the belief of being a sacred plant by the Hindu religion. It is distributed throughout India and extends up to northwest Himalaya, Kashmir, West Bengal, central and southern Bihar, Orissa, Maharashtra, south India, and northeast India (Assam, Manipur, and Mizoram, etc.). In India, it grows in ponds, lakes, and tanks. *Nelumbo nucifera* Gaertn is grown in China, Japan, and India in terraced fields and in Indian country due to its fragrant flowers, seeds, fruits, and rhizomes (Anonymous 1966). The propagation of lotus is done by seeds and rhizomes in March to April mainly in ponds, and rhizomes are ready to harvest in October. Flowering takes place during hot and rainy seasons and seeds ripen toward the end of rains.

2.1.3 Botanical Description

Taxonomic Classification
(Mukherjee et al. 1996a, b)

Kingdom:	Plantae
Sub Kingdom:	Tracheobionta
Super Division:	Spermatophyta
Division:	Magnoliophyta
Class:	Magnoliopsida
Subclass:	Magnoliidae
Super order:	Protaenae
Order:	Proteales
Family:	Nelumbonaceae/Nymphaeaceae
Genus:	Nelumbo
Species:	*Nelumbo nucifera* Gaertn.

2.1.4 Nutritional Value

The leaves, rhizomes, and stems of *Nelumbo nucifera* Gaertn are appetizing and can be prepared as vegetables (Anonymous 1992) or pickled and served with syrup (Phillips and Rix 1995). The lotus corolla find use in soups and garnishes, whereas the lotus stamens as added as tea additive (Ibrahim and Eraqy 1996). Lotus seeds can be used as popcorn, powdered, or eaten dry while the roasted seeds act as coffee substitute (Ling et al. 2005). Lotus known as Nadru in Kashmir is profoundly correlated with its culture and economy. Nadru-based cuisines like lotus stem and yoghurt curry (Nadru yakhni) stem rogan josh, stem-palakh, stem kabab, stem pickles, stem fish, etc. are an integral part of every Kashmiri religious, social, and/or cultural occasion. The nutritive value analyses of raw lotus plant parts done in the United States report the proximate composition per 100 g value as given in Table 2.1.

2.2 Antioxidant Properties and Phytochemistry of *Nelumbo nucifera* Gaertn

Biological action of phytochemicals is related with their antioxidant prospective (Dey et al. 2016). The scientific investigations on the antioxidant activities of various lotus parts are highest, equaling to 18 in in vitro and 8 in in vivo conditions. Yet, no single index is believed to be adequate for determination of the entire antioxidant capability (Feng et al. 2016; Venkatesh and Dorai 2011; Karadag et al. 2009), owing to variety in reaction of chemical constituents (Lopez-Alarcon and Denicola 2013). According to Feng et al. (2016), inconsistencies are present in the outcomes acquired from embryos of different cultivars of lotus through the use of 2, 2-diphenyl-1-picrylhydrazyl (DPPH) and Ferric Reducing Antioxidant Power (FRAP) assays. Hitherto 12 phenolics and 89–90 flavonoids (out of which 47 were flavonols, 25–26 were flavones, 8 were flavan-3-ols, 4 were flavanons, and 5 were anthocyanins) were reported from leaf pulp of lotus, veins of lotus leaves, stalk of lotus leaves, receptacle of lotus, epicarp of lotus, coat of lotus, kernel of lotus, embryo of lotus, androecium, flower petals, gynoecium, and stalk of lotus plant. The seeds (Rai et al. 2006), leaves (Huang et al. 2010), rhizomes (Yang et al. 2007), and stamens (Hyun et al. 2003) of lotus plant exhibit antioxidant actions. Jung et al. (2003) anticipated that the OH at the carbon-3 locations structurally adds to the antioxidant property of flavonoids present in the stamens of lotus plant. When a glycoside hides the OH at the carbon-3 loci, half maximal inhibitory concentration (IC_{50}) values reduce severely. Kaempferols have excellent antioxidant activities in 2, 2-Diphenyl-1-Picrylhydrazyl, peroxynitrite scavenging activity (PSA), and overall reactive oxygen species; while kae 3-GlnPyr-methylester and kae 3-GlnPyr illustrated slighter scavenging properties in DPPH and PSA. Kae 3-GluPyr and Kae 3-GalPyr show activity merely in the assay of peroxynitrite scavenging activity (Jung et al. 2003). Hyun et al. (2006) observed analogous outcome for IC_{50} antioxidant rates of isorhamnetin glycosides in male reproductive part of lotus. The glycosylation affects antioxidant ability, solubility of aglycones, and the stability of aglycones (Zhu et al. 2017). The flavonoids of lotus with C-glycosides present in the embryo of lotus demonstrate high in vitro antioxidant capability compared to O-glycosides (Zhu et al. 2017). Polyphenols possess antioxidant activity responsible for many health advantages (Lee et al. 2012; Devkota et al. 2015). The antioxidant activities of phenolic acids are directed by their chemical structures. The antioxidant activity of phenols enhances with the increase in number of hydroxyl groups (Moure

Table 2.1 Nutritive value of lotus root and lotus seeds, raw per 100 g

Nutrient	Root {amount}	Seeds {amount}	Unit
Ash	0.97	1.07	g
Calcium, Ca	45	44	mg
Carbohydrate, by difference	17.23	17.28	g
Energy	74	89	kcal
Energy	311	372	kJ
Fiber, total dietary	4.9		g
Protein	2.6	4.13	g
Total lipid (fat)	0.1	0.53	g
Water	79.1	77	g
Copper, Cu	0.257	0.094	mg
Folate, DFE	13	28	μg
Folate, food	13	28	μg
Folate, total	13	28	μg
Iron, Fe	1.16	0.95	mg
Magnesium, Mg	23	56	mg
Manganese, Mn	0.261	0.621	mg
Niacin	0.4	0.429	mg
Pantothenic acid	0.377	0.228	mg
Phosphorus, P	100	168	mg
Potassium, K	556	367	mg
Retinol	0	0	μg
Riboflavin	0.22	0.04	mg
Selenium, Se	0.7		μg
Sodium, Na	40	1	mg
Thiamin	0.16	0.171	mg
Vitamin A, IU	0	13	IU
Vitamin A, RAE	0	1	μg
Vitamin B-6	0.258	0.168	mg
Vitamin C, total ascorbic acid	44	0	mg
Zinc, Zn	0.39	0.28	mg
Fatty acids, total saturated	0.03	0.088	g
14:0	0	0.001	g
16:0	0.028	0.077	g
18:0	0.001		g
Fatty acids, total monounsaturated	0.02	0.104	g
16:1	0.002	0.062	g
18:1	0.014	0.012	g
20:1	0.002	0.031	g
Fatty acids, total polyunsaturated	0.02	0.312	g
18:2	0.014	0.285	g
18:3	0.006	0.027	g
Alanine	0.054	0.239	g
Arginine	0.088	0.338	g

(continued)

Table 2.1 (continued)

Nutrient	Root {amount}	Seeds {amount}	Unit
Aspartic acid	0.369	0.505	g
Cystine	0.022	0.054	g
Glutamic acid	0.139	0.957	g
Glycine	0.156	0.221	g
Histidine	0.038	0.115	g
Isoleucine	0.054	0.205	g
Leucine	0.069	0.326	g
Lysine	0.094	0.264	g
Methionine	0.022	0.072	g
Phenylalanine	0.047	0.206	g
Proline	0.136	0.344	g
Serine	0.06	0.252	g
Threonine	0.051	0.2	g
Tryptophan	0.02	0.059	g
Tyrosine	0.029	0.1	g
Valine	0.055	0.266	g

Source: United States Department of Agriculture Agricultural Research Service (2019). Food Data Central: Food and Nutrient Database for Dietary Studies with Standard Reference Legacy Release-169250 and 16859. Retrieved 10-03-2020. www. *fdc.nal.usda.gov*

et al. 2001). The seed gallic acid which has 3-hyroxyl (OH) groups showed higher antioxidant potential than caffeic and chlorogenic acid which have 2-hyroxyl groups and p-hydroxybenzoic acid having 1-hyroxyl group (Yen et al. 2005). The polysaccharides also show scavenging action and reduction property of leaf extracts of this plant, besides phenolic acids and flavonoids (Zhang et al. 2015). The seeds of lotus plant encompass alkaloids, saponins, phenolic acids, and carbohydrates which possess a great degree of antioxidant activity (Mukherjee et al. 2010a, b).

2.2.1 Antioxidant Properties and Phytochemicals Present in Fruit/ Receptacle of *Nelumbo nucifera*

Various scientific investigations are available on the separation and identification of the chemical compounds present in the receptacle of lotus plant. Ling et al. (2005) improved, characterized, and scrutinized the antioxidant potential of procyanidins of *Nelumbo nucifera* Gaertn receptacle. With mass spectroscopy, Ling et al. (2005) inferred presence of huge concentrations of dimers than monomers and tetramers of catechin and epicatechin procyanidins in sample extracts. The natural polyphenols in seedpod of lotus signifies its source as antioxidants. Wu et al. (2013) isolated and verified five diverse flavonol glycosides in receptacle of lotus plant out of which hyperoside and isoquercitrin were antioxidants. Hu (2005) analyzed the nutritive value and antioxidant capability of lotus receptacle wherein they obtained and identified quercetin-3-*O*-β-D-glucopyranoside – a dietary flavonoid in lotus.

The receptacle of lotus plant contains judicious but noteworthy magnitude of key secondary metabolites which are phenolics. Phenolics exhibit a variety of bio-pharmacological effects in conjunction with antioxidation (Ling et al. 2005), such as improvement in learning ability and memory proficiencies (Gong et al. 2008), protection from experimental myocardial wounds and ischemic disorders (Zhang et al. 2004), radio protecting action (Duan et al. 2010), and antitumor effects (Duan et al. 2004). The quantity of total phenolic acids ranged from 255.65 to 477.61 mg/g, flavonoid compounds ranged from 353.31 to 540.84 mg/g, and pro-anthocyanidins ranged from 112.41 to 358.42 mg/g which are responsible for antioxidant capability of receptacle of lotus extract in 11 diverse cultivars of China. The methods used for their estimation were DPPH, 2,2′-Azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) diammonium salt, superoxide anion radical scavenging, reducing power, activities of antioxidation, metal chelation, and β-carotene bleaching. In DPPH free radical scavenging activity (IC_{50}), the entire phenolic acid content ($r = 0.9529$) showed positive correlation (Zheng et al. 2012).

2.2.2 Antioxidant Properties and Phytochemicals Present in Seed of *Nelumbo nucifera* Gaertn

The linoleic acid, an unsaturated fatty acid, was mainly copious at 0.285 g/100 g of seeds of lotus plant (Lim 2016). The annexin proteins and a myriad of natural compounds which function as antioxidants were reported in seeds of lotus (Chu et al. 2012). Three alkaloids, known as neferine, liensine, and isoliensinine, were efficaciously separated and identified from seeds of *Nelumbo nucifera* Gaertn through liquid chromatography (Chen et al. 2007). Liu et al. (2009) furthermore reported analogous results from crude extracts of embryos of lotus seeds. Besides, other major secondary metabolites, Mehta et al. (2013) reported dauricine alkaloid, roemerine alkaloid and pronuciferine alkaloid from the seeds of lotus plant. Diverse flavonoids, for example, rutin, Syringetin-3-*O*-glucoside, and astragalin have been isolated in seed coats of *Nelumbo nucifera* Gaertn plant (Lim 2016). Youn et al. (2010) isolated and analyzed structures of four diverse alkyl 4-hydroxybenzoates from seeds of lotus plant by NMR spectroscopy.

The mass of seed of *Nelumbo nucifera* Gaertn has 3.74% integuments, 3.03% plumule, and 93.23% dicotyledons. *Nelumbo nucifera* Gaertn contains glutathione content of 13 g in its plumule and 164 g in its cotyledon. *Nelumbo nucifera* Gaertn seeds show abundance of asparagin, fats, starch, proteins, and tannins (Toyoda 1966) and a variety of minerals and nutritional elements for example; K-potassium (28.5%), chromium (0.0042%), magnesium (9.20%), Na-sodium (1.00%), Ca-calcium (22.10%), Mg-manganese (0.356%), Co-copper (0.0463%), zinc (0.0840%), and iron (0.1990%), overall ash (4.50%), crude content of carbohydrates (1.93%) and dietary fibre (10.60%), moisture (10.50%), fats (72.17%), and proteins (2.70%) (Indrayan et al. 2005). The major secondary metabolite alkaloids of seeds of *Nelumbo nucifera* Gaertn are pronuciferine, lotusine, nuci-ferine, liensinine, neferine, dauricine, isoliensinine, roemerine, and armepavine (Qian 2002; Wu et al. 2004; Liu et al. 2006; Wang et al. 1991; Furukawa et al. 1965; Tomita et al. 1965; Furukawa 1966), Procyanidin (Ling et al. 2005). The gallic acid, D(–)-3 0-bromo-O-methylarmepavine D–1,2,3,4-tetrahydro-6-methoxy-1-(p-methoxy benzyl)-2-methyl-7-isoquino-linol, carbohydrates, and saponins (Rai et al. 2006) are also present in seeds. The seed polysaccharides isolated and characterized by acid hydrolysis and methylation are four categories of monosaccharide, which are D-mannose, D-galactose, D-glucose, and L-arabinose (Das et al. 1992).

The seed extract prepared in ethanol demonstrates antioxidant action by the use of 2, 2-diphenyl-1picrylhydrazyl (DPPH) assay, wherein free radical scavenging results showed 6.49 mg/ml median inhibition concentration (IC_{50}) (Sohn et al. 2003). *Nelumbo nucifera* Gaertn seeds and receptacle possess activities of antioxidation and free-radical scavenging. The hydro-alcoholic seed extract possess antioxidant potential as revealed by in vitro and in vivo models, DPPH assay, and nitric oxide methods (Rai et al. 2006), wherein the complete phenolics amount was reported as 7.61% with strong free radical scavenging capability showing low median inhibition concentration (IC_{50}) values (16.12 μg/ml) compared to a standard free radical scavenger, that is, rutin (IC_{50}, 18.95 μg/ml) 50 and 84.86 ± 3.56 mg/ml which is reduced than rutin (IC50: 152.17 μg/ml) by the DPPH and nitric oxide assays respectively (Rai et al. 2006).

In vivo study of the hydroalcoholic extract of lotus seeds in Wistar rats at a dosage of 100 mg/kg and 200 mg/kg for 4 days followed by the carbon tetrachloride action lead to considerable dose-dependent enhancement in levels of SOD, catalase, and causes reduction in TBA reactive substances comparative to 100 mg/kg dosage to that of vitamin E at 50 mg/kg (Jiqu et al. 2010). The Swiss Albino mice show no signs and symptoms of acute toxicity up to dosage of 1000 mg/kg body weight (Gutteridge and Halliwell 2000). The macrophage RAW264.7 cell lines showed major free radical scavenging against ROS, and defensive effects against sodium nitroprusside, peroxynitrite induced cytotoxicity, and DNA damage when treated with seed extracts of lotus plant. In comparison to 0.1% butylated hydroxytoluene (BHT), the seed procyanidin and tannin exhibit lipid lipoxygenase inhibition, auto-oxidation, and free radical scavenging ability. Procyanidin at concentration of 62.5 mg/ml showed IC50 value of 21.6 mg/ml and inhibited lipoxygenase action by over 90% (Rai et al. 2006; Ling et al. 2005). Procyanidin and tannin of seed pods have numerous pharmacological properties along with auto-oxidation of lipids, inhibition of lipoxygenase, and free radical scavenging activity paralleled to 0.1% BHT, which inhibits autoxidation of lard (Yen et al. 2006) and remodels age-linked antioxidant deficits in older rats (Ling et al. 2005). Ushimaru et al. (2000) investigated the enzymes with antioxidative potential and their alterations in seedlings of lotus plant, which reacts to deficiency in oxygen levels by the process of germination under aquatic conditions. The enzymatic properties of superoxide dismutase (SOD), dehydro-ascorbate reductase, and glutathione reductase were lesser in lotus seedlings subjected to germination in submerged conditions along with darkness (SD) compared to seedlings subjected to germination in air along with darkness (AD) (Ushimaru et al. 2000).

2.2.3 Antioxidant Properties and Phytochemicals Present in Rhizomes of *Nelumbo nucifera* Gaertn

The fresh rhizomes of lotus plant have starch (31.2%) devoid of distinctive flavor or odor (Mukherjee et al. 1995b). The methanolic lotus rhizome extract possesses a betulinic acid which is a steroidal triterpenoid (Mukherjee et al. 1997c). The fresh rhizome has 83.80% water content, 0.11% fat content, 1.56% reducing sugar content, 0.41% sucrose content, 2.70% crude protein content, 9.25% starch content, 0.80% rhizome fibre content, 1.10% ash content, 0.06% Ca-calcium content, thiamine content of 0.22 mg/100 g, riboflavin content of 0.6 mg/100 g, niacin content of 2.10 mg/100 g, ascorbic acid content of 1.5 mg/100 g, asparagine-like amino acid content of 2.00%, and oxalate content of 84.3 mg/100 g (Mukherjee et al. 1996a, b, c).

The antioxidant potential of the methanol rhizome extract and acetone rhizome extract by DPPH assay wherein the maximum DPPH scavenging action was found at 66.73 mg/l in methanol and 133.3 mg/l in acetone (Yang et al. 2007). The methanol rhizome extract revealed an elevated coefficient of antioxidant action contrast to that of ascorbic acid. The lotus rhizome knot showed radical scavenging property which was quantified by spectrophotometer and electron spins resonance (Hu and Skibsted 2002).

2.2.4 Antioxidant Properties and Phytochemicals Present in Flowers of *Nelumbo nucifera* Gaertn

Lotus flowers vary in color which became the basis for investigating the phytochemical constitution of the lotus plant. Jung et al. (2003) had obtained seven previously reported flavonoids in androecia of lotus plant together with a few alternatives of the kaempferol. Anthocyanins were also found in flower petals of the lotus plant (Yang et al. 2009). Deng et al. (2013), through HPLC analysis, identified and quantified the flavonoid compounds of 108 cultivars from petals of flowers of lotus plant and found 19 different flavonoid compounds from the class of anthocyanins, flavonols, and flavones. Chen et al. (2013) reported 5 variants of anthocyanins and 20 supplementary flavonoids from petal extracts of 12 varied genotypes wherein the cyanidin 3-*O*-glucoside is one of the reported anthocyanins. The flower stamens and petals comprise approximately indistinguishable array of astragalin flavonoid, rutin flavonoid, and myricetin 3-*O*-galactoside flavonoids (Lim 2016). Further, beta-carotene carotenoids were reported from flowers of 4 *Nelumbo nucifera* Gaertn varieties growing in two different provinces of Thailand (Phonkot et al. 2010).

The flavonoids with potent antioxidant activities recognized in androecia of *Nelumbo nucifera* Gaertn are kaempferol and its seven glycosides: kaempferol 3-O-β-D-glucopyranoside, kaempferol 3-O-β-D-galactopyranoside, kaempferol-3-O-β-D-glucuronopyranoside, kaempferol 3-O-a-L-rhamnopyranosyl-(1–2)-β-D-glucuronopyranoside, kaempferol 7-O-β-D glucopyranoside, kaempferol 3-O-a-L-rhamnopyranosyl-(1-6)-β-D-glucopyranoside, quercetin 3-O-β-D-glucopyranoside, kaempferol 3-O-a-Lrhamnopyranosyl-(1-2)-β-D-glucopyranoside, myricetin 3 0, 5 0-dimethylether 3-O-β-D-glucopyranoside, kaempferol 3-O-β-D-glucuronopyranosyl methyl ester, nelumboroside A and nelumboroside B and two isorhamnetin glycosides known as isorhamnetin 3-O-β-D-glucopyranoside, and isorhamnetin 3-O-a-L-rhamnopyranosyl-(1_6)-β-D-glucopyranoside (Hyun et al. 2006; Jung et al. 2003; Lim et al. 2006). Lim et al. (2006) reported non-flavonoids from stamen extract which includes adenine, arbutin, and β-sitosterol glucopyranoside and myo-inositol. The methanolic stamen and ethyl acetate stamen extracts were used for studying the antioxidant activity of stamen of lotus flower in scavenging genuine peroxynitrites (ONOO-), DPPH, and ROS (Jung et al. 2003).

The kidney homogenates by use of 2v, 7′-dichloro-dihydrofluoresce in diacetate scavenges DPPH free radicals and peroxynitrites ($ONOO^-$) and inhibits ROS generation by DCHF-DA in lotus (Jung et al. 2003). The IC_{50} value (DPPH) of stamen of lotus solutions in methanol of Pathum, Boontharik, Sattabongkot, and Sattabuut were 68.30_6.30, 62.22_ 4.00, 31.60_ 3.40, and 40.90_1.50 _g.mL-1, respectively, whereas of mixed-solvent solutions of Pathum, Boontharik, Sattabongkot, and Sattabuut were 2.21_0.06, 2.23_0.05, 1.29_ 0.02, and 1.83_0.07 mg.mL-1, respectively. The IC_{50} value (DPPH) of Sattabongkot solutions in both solvents was drastically lesser than that of others ($p < 0.05$, at the confidence level of 95%), while the methanol solutions were higher comparative to mixed solvents by 40 folds. The methanol solution retains flavonoids owing to their analogous polarity (Phonkot and Aromdee 2006; Harborne 1998). The mixed-solvent solution retained carotenoids (Phonkot and Aromdee 2006; Horwitz 2000).

2.2.5 Antioxidant Properties and Phytochemicals Present in Leaves of *Nelumbo nucifera* Gaertn

Nelumbo nucifera Gaertn leaves have potential as a resource of antioxidants. A range of alkaloids N-nornuciferine, (−)-caaverine, (−)-nuciferine, and roemerine were found in the plant leaves (Lim 2016). A total of 15 phytochemical compounds were isolated and identified from leaves of lotus plant, out of which lysicamine, (−)-nuciferine, and (−)-asimilobine were reported as potential natural antioxidants (Liu et al. 2014). The anonaine, liriodenine, and astragalin phytochemicals were also reported in lotus leaves (Mehta et al. 2013). Flavonoids, for example, astragalin, rutin, and quercetin, have been efficaciously isolated from ethanolic leaf extracts of lotus plant (Ohkoshi et al. 2007). Goo et al. (2009) isolated six diverse flavonoid quercetin forms from the methanolic extract of leaves of lotus plant. Chen et al. (2012) mined 13 diverse flavonoids from leaves of *Nelumbo nucifera* Gaertn. Out of which five flavonoids were novel in leaves of lotus plant identified by the use of an improved extraction technique and HPLC investigative method. The above-mentioned reports accentuate the varied amount of bioactive compounds of *Nelumbo nucifera* Gaertn leaves. The overall phenolic acids content of leaf extract of *Nelumbo nucifera* Gaertn plant was decided by Folin–Ciocalteau assay (Zoecklin et al. 1995).

The phenolic content of *Nelumbo nucifera* Gaertn leaves comprises rutin, quercetin, and gallic acid (Lim 2016).

The combined gas/LC/MS has revealed that lotus leaves contain numerous alkaloids. The (+)-1(R)-coclaurine and (−)-1(S)-norcoclaurine benzylisoquinoline alkaloids showed presence in extracts of leaves. The non-phenolic fractions of leaves of *Nelumbo nucifera* Gaertn revealed majority compounds with retention data and mass spectra indistinguishable from anonaine, roemerine, pronuciferine, nuciferine, N-nornuciferine, liriodenine (Mukherjee et al. 1996a, b; 2009), and armepavine and N-methyl-coclaurine phenolic bases as well are present (Kunitomo et al. 1973) Dehydroemetine, remerine, armepavine, roemerine, O-nornuciferine, dehydronuciferine, nuciferine, dehydroanonaine, isoliensinine, N-methylisococlaurine, anonaine, negferine, pronuciferine, liensinine, asimilobine and lirinidine glycoside, nelumboside, flavonoids such as quercetin, quercetin 3-O-aarabinopyranosyl-(1! 2)-_-galactopyranoside, quercetin-3-O-_-D-glucuronide, rutin, (+)-catechin, hyperoside, isoquercitri, and astragalin and leuco-anthocyanidin (leucocyanidin and leucodelphinidin) showed presence in leaves of lotus and petioles (Tomita et al. 1961; Kupchan et al. 1963; Shoji et al. 1987; Nagarajan et al. 1966; Kashiwada et al. 2005; Ohkoshi et al. 2007).

Wu et al. (2003) reported hydrogen peroxide-mediated cytotoxicity in Caco-2 cells to explore the prospective antioxidant capability of the methanol extract from *Nelumbo nucifera* Gaertn leaves. A dose-dependent protective influence against ROS-induced cytotoxicity was detected on treatment of Caco-2 cells with 10 mM hydrogen peroxide and methanol extract of leaves (0.1 mg/ml to 0.3 mg/ml). Lotus extracts revealed concentration-dependent antioxidant potential against hemoglobin-induced linoleic acid peroxidation and Fenton reaction-mediated plasmid DNA oxidation (Wu et al. 2003; Huang et al. 2010a, b). The ethanolic extract of lotus leaves showed in-vivo antioxidant action at 100 mg/kg counter to carbon tetrachloride (CCl4) induced liver toxicity in Sprague–Dawley rats and KM mice comparative to the standard which was a hepatoprotective drug (silymarin) of 100 mg/kg (Wang 2010). The structures of major chemical constituents present in *Nelumbo nucifera* Gaertn are given in Fig. 2.1.

2.2.6 Antioxidant Properties of Products Prepared from *Nelumbo nucifera* Gaertn

Scientific investigators have endeavored to incorporate the extracts of different parts of *Nelumbo nucifera* Gaertn like leaves, roots, flowers, and epicarp of seed into different products, together with animal meat, syrup, broth, and liquor and scrutinized their consequence on antioxidant activities.

According to Huang et al. (2011), the root knot and extracts of *Nelumbo nucifera* Gaertn leaves at 3% (w/w) act as antioxidant agent against porcine and bovine minced meat. The lotus root knot was extra effectual against oxidation of lipids during meat storage conditions Extracts of epicarp of lotus seeds equal to 100 μg/mL concentration retard early oxidation of the lipids in homogenates of pork during

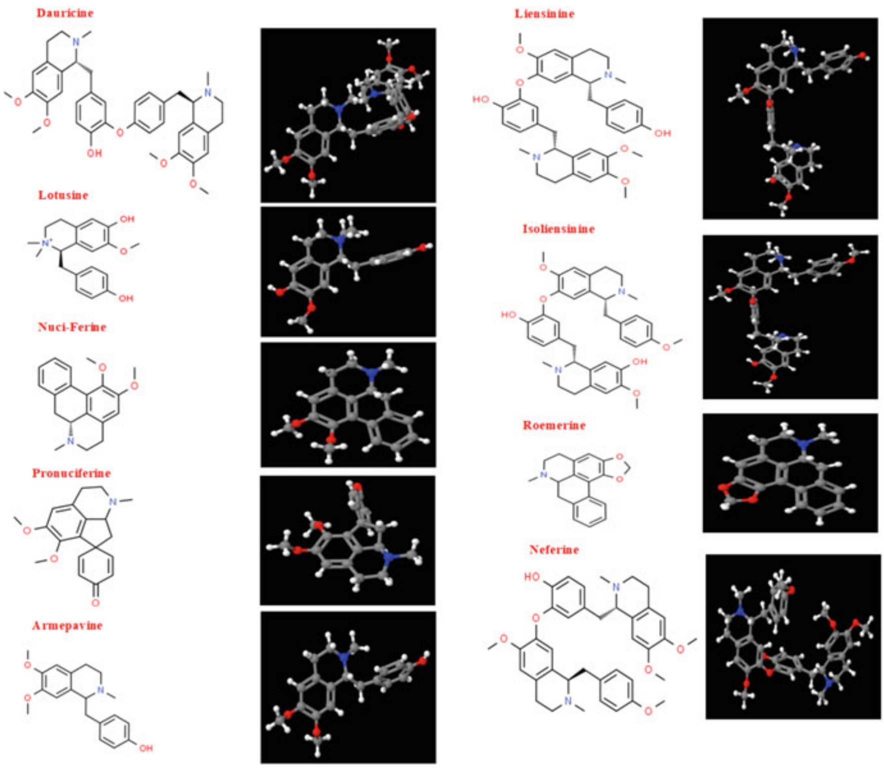

Fig. 2.1 Chemical structure (2-dimensional and 3-dimensional) of major phytochemicals present in *Nelumbo nucifera* Gaertn

storage conditions (Qi and Zhou 2013). On incorporation of leaf powder of lotus plant during storage, the thiobarbituric acid reactive substances of the refrigerated chicken pastry improved (Choi et al. 2011). Shukla et al. (2016) reported a substantial enhancement in both TPC (521 mg/mL) and TFC (63 mg/mL) was reported throughout fermentation in syrup developed with incorporation of root of lotus plant. This syrup moreover exhibited elevation in antioxidation action, with IC_{50} value of 87.25% in DPPH assay, 99.52% in NO assay, and 44.4% in SOD assay. Additionally, syrup showed anti-tyrosinase action elevation up to 49.8%. Hwang et al. (2015) reported that broth of *Nelumbo nucifera* Gaertn leaves under fermentation for above 180 days displayed antioxidant action analogous to ascorbic acid. Lee et al. (2005) reported that leaves and flowers of *Nelumbo nucifera* Gaertn were practiced to produce customary Korean liquor with antioxidation ability plateau of 80% inhibition at concentration of >25 µg Korean liquor.

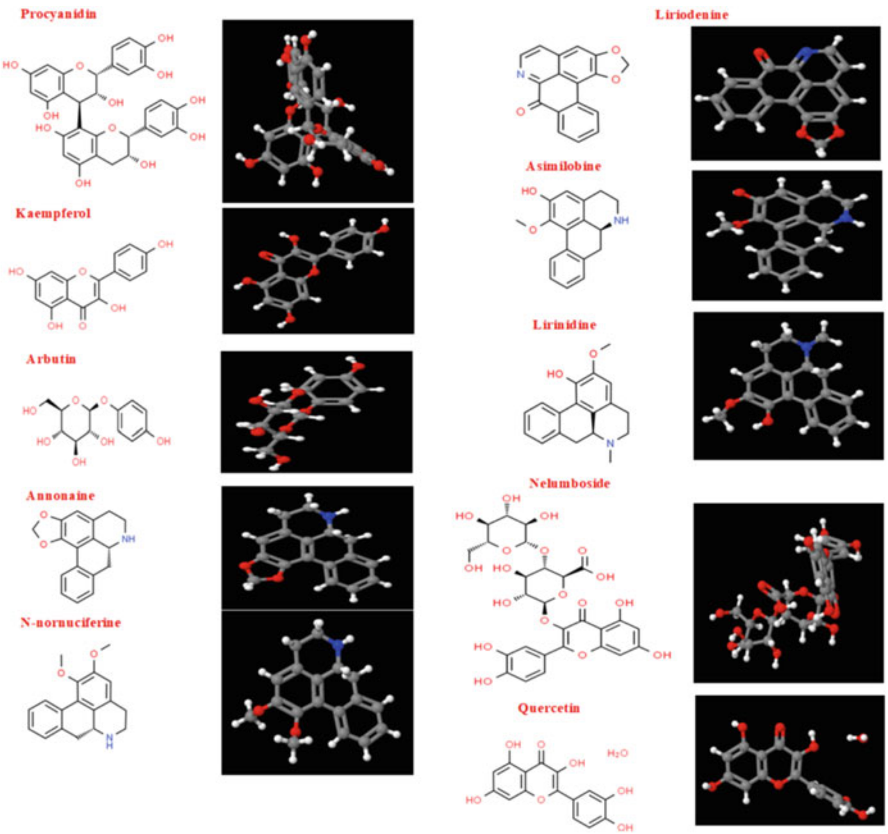

Fig. 2.1 (continued)

2.3 Potential Health Benefits

Plants have been exploited as a resource of drugs by human since antiquity. The aboriginal comprehension of several traditional communities has been devised, documented, and ultimately developed as structured medicinal systems, for example, Ayurveda, Siddha, Unani, and other medicinal systems outside India. *Nelumbo nucifera* Gaertn is fundamentally exploited in Ayurvedic and Unani systems of medicine as cooling, narcotic, astringent, diuretic, and antidiabetic. All the parts of *Nelumbo nucifera* Gaertn are employed therapeutically in contradiction of different human diseases in oriental medicine (Zhou et al. 2009). Ayurveda advocates use of this plant as diuretic and antihelmintic, and for alleviation of strangury, nausea, leprosy, disorders of skin, nervous fatigue (Khare 2004; Sridhar and Bhat 2007), cancer, inflammation of tissue, and as an antidote against toxic substances (Chopra et al. 1956; Liu et al. 2004). Lotus effectively acts as a prospective antioxidant (Rai

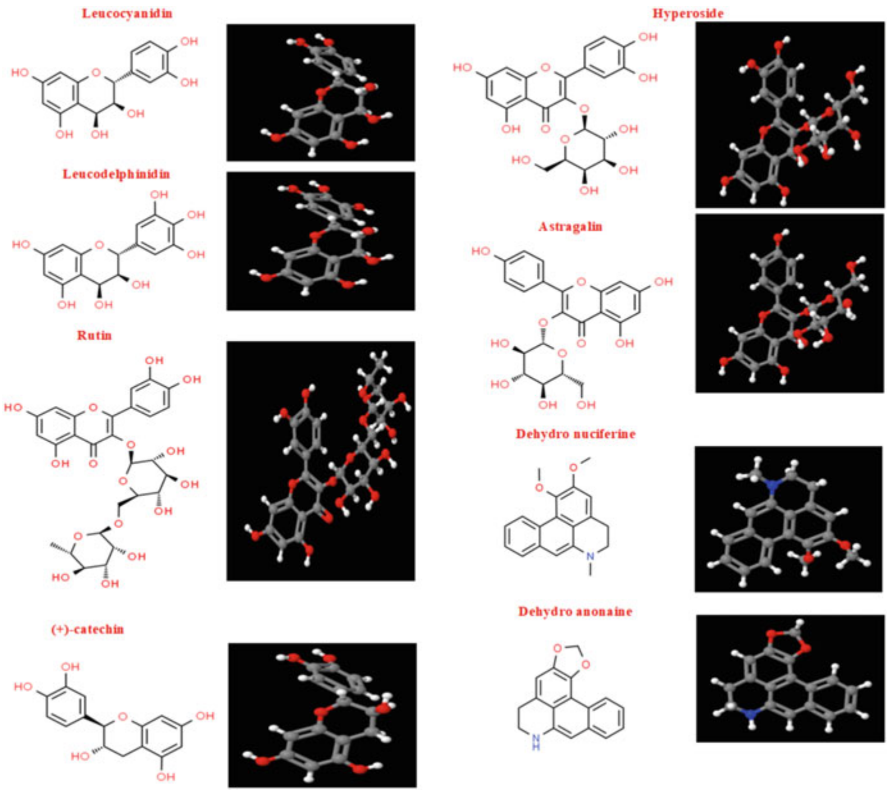

Fig. 2.1 (continued)

et al. 2006), antipyretic (Deepa et al. 2009), showed antiplatelet (Brindha and Arthi 2010b) and hypoglycemic activity (Mani et al. 2010). Conventionally all parts of *Nelumbo nucifera* Gaertn have therapeutic properties.

Lotus rhizomes have nutritive value; they cure dysentery and unremitting dyspepsia; act as diuretic, cholagogue, and demulcent for hemorrhoids; and aid to cure fever (Mukherjee et al. 1997a, c; Kirtikar and Basu 1975; Chatterjee and Pakrashi 1991). The fresh and fleshy rhizome is sweet and aromatic; possess tonic effect; and are consumed for their nutritious value and as a curry known as *Nadru Yakhni* in Kashmir province of Jammu and Kashmir, India. The rhizome when heated in gingelly oil and rubbed on head of a person provides cooling effect to the rubbed area and eyes. It is excellent in cases of dysentery, diarrhea, and dyspepsia. The rhizome paste is applied in ringworm and cutaneous infections (Anon 1966; Nadkarni 1954). The saline lotus rhizome extract possesses bacteriostatic potential (Anonymous 1966). Lotus **leaves** alleviate hyperlipidemia, epistaxis, hematemesis, hematuria, hemoptysis, and metrorrhagia (Onishi et al. 1984). The paste of fresh *Nelumbo nucifera* Gaertn leaves along with sandalwood is useful in the vicinity of burning heat of the skin. The leaf stakes provide cooling effect to forehead in cephalalgia; the milky juice is given in diarrhea (Kirtikar and Basu 1933; Nandkarni 1954) and the tender leaves act as refrigerant in fever. The **flowers** of *Nelumbo nucifera* Gaertn treat fever, diarrheal disorder, cholera, and gastric ulcers (Chopra et al. 1956). *Nelumbo nucifera* Gaertn **seeds** are utilized in folk medications to cure inflammation of tissue, various types of cancers, diuretics, and the skin syndromes (Mukherjee et al. 2010a). Lotus *Nelumbo nucifera* Gaertn **receptacles** are occasionally utilized as a traditional medication for hemostatic purposes (Ling et al. 2005). The Lotus *Nelumbo nucifera* Gaertn **seeds** and **fruits** are exploited as a fitness foodstuff in Asia, and in treating deprived digestion, chronic diarrheal disorder, spermatorrhea, insomnia, enteritis, halitosis, heart palpitations, dermatopathy, menorrhagia, leucorrhoea, leprosy, tissue inflammation, cancer, fever, cardiac problems, antiemetic, antidote, diuretic, and refrigerant (Chopra et al. 1956; Mukherjee et al. 1996a, b; Varshney and Rzóska 1976). The powder of seeds of *Nelumbo nucifera* Gaertn blended with honey is beneficial in treatment of cough (Khare 2004). The seed embryos are employed in traditional Chinese medicine (TCM) for conquering disorders of nervous system, insomnia, towering fevers, and cardiovascular syndromes (Chen et al. 2007).

The numerous pharmacological activities of *Nelumbo nucifera* Gaertn reported include antioxidant (Hu and Skibsted 2002; Hyun et al. 2006), hepatoprotective (Rao et al. 2005), anti-analgesic (Chakravarthi and Gopakumar 2009), immunomodulatory (Mukherjee et al. 2010a), antifertility (Chauhan and Agarwal 2009), psychopharmacological (Mukherjee et al. 1996d), antipyretic (Sinha et al. 2000; Mukherjee et al. 1996e), anticancer (Chopra 1958; Liu et al. 2004; Liu et al. 2006), antiviral (Kuo et al. 2005; Kashiwada et al. 2005), hypoglycemic, antidiarrheal, antifungal, antibacterial, anti-inflammatory, and diuretic activities (Mukherjee et al. 1995a; Mukherjee et al. 1996c; 1997a, b). The other reported pharmacological properties of *Nelumbo nucifera* Gaertn are given in Table 2.2.

2.4 Conclusions and Future Pathways

Nelumbo nucifera Gaertn possess great momentous advantages in contradiction of the free radicals and ROS species damage. *Nelumbo nucifera* Gaertn is testified to contain an assortment of chemical ingredients which would function as frontrunners in the exploration for novel therapeutic agents. With the accessibility of principal studies, additional scientific investigations on *Nelumbo nucifera* Gaertn should be designed to probe the molecular mechanisms of action by means of specific biological screening models (in vitro) and clinical trials (in vivo) and biosynthetic pathways of isolated phytoprinciples to discover novel leads and the genes responsible from them for modern day drug designing. Furthermore, scientific investigations need to be extended to develop and standardize the procedures for proficient mining and confirmation of active principles of this traditional and medicinal herb *Nelumbo nucifera* Gaertn for the purpose of their utilization in precise herbal formulations for curing various human disorders devoid of side effects

Table 2.2 Pharmacological properties of different parts of *Nelumbo nucifera* Gaertn

S. No	Part used	Ethno-medicinal use/Pharmacological activity	Reference
1	Leaves	Diarrhea	Nguyen (1999), Ku-Lee et al. (2005)
		High fever	
		Hemorrhoids	
		Leprosy	
		Lipolytic	Ohkoshi et al. (2007)
		Anticancer	Arjun et al. (2012)
		Antiobesity	Ono et al. (2006)
		Cardiovascular activity	Shoji et al. (1987)
		Hypocholesterolemic	Onishi et al. (1984)
2	Leaf extracts	Analgesic activity	Bera et al. (2011)
		Anthelmintic activities	Lin et al. (2014)
		Antiobesity and hypolipidemic	Du et al. (2010)
3	Leaves and stem	Hematopoietic	Patel et al. (2012)
4	Leaf, flower, seed	Cosmetic agent	Kim et al. (2011)
5	Lotus liquor from leaves & blossoms	Antioxidant, reduces risk of chronic syndromes	Ku-Lee et al. (2005)
6	Rhizome	Diuretic	Mukherjee et al. (1996a)
		Psycho-pharmacological	Mukherjee et al. (1996b)
7	Rhizome extract	Antidiabetic	Mukherjee et al. (1997a)
		Antiobesity	Ono et al. (2006)
8	Flowers, rhizome	Hypoglycemic	Huralikuppi et al. (1991), Lee et al. (2001)
		Antipyretic activity	Mukherjee et al. (1996c), Sinha et al. (2000)
		Antidiabetic	Rakesh et al. (2011)
9	Leaves, flower, rhizome	Antioxidant	Wu et al. (2003), Jung et al. (2003), Hyun et al. (2006)
10	Flower	Antimicrobial activity	Brindha and Arthi (2010a)
		Anti-platelet	Brindha and Arthi (2010b)
		Aldose reductase inhibitory	Lim et al. (2006)
		Vasodilating effects, antihypertensive, and antiarrhythmic abilities	Ku-Lee et al. (2005)
		Antioxidant	Krishnamoorthy et al. (2009)
		Antibacterial, antioxidant	Venkatesh and Dorai (2011)
		Antioxidant, free radical scavenging	Durairaj and Dorai (2014)

(continued)

Table 2.2 (continued)

S. No	Part used	Ethno-medicinal use/Pharmacological activity	Reference
11	Beverages of flower	Hypertension, cancer, feebleness, body heat balance	Saengkhae et al. (2008)
12	Androecia	Consolidation of kidney function, disorders of male sexuality, leucorrhea of females	Nguyen (1999)
		Aphrodisiac	Vahitha Bi et al. (2012)
15	Flower receptacles	To stop bleeding and to eliminate stagnated blood	Ku-Lee et al. (2005)
16	Seed	Antiproliferative	Yu and Hu (1997)
		Antifibrosis	Xiao et al. (2005)
		Antifertility	Mutreja et al. (2008)
		Antidepressant, anti-inflammation	Bi et al. (2006)
		Anti-ischemic/cardiovascular symptoms	Kim et al. (2006)
17	Ripe seeds	Astringent action, chronic diarrhea	Nguyen (1999)
		Spleen tonic	Follett and Douglas (2003)
18	Seed powder	Cough	Khare (2004)
19	Seed extracts	Hepatoprotective, free radical scavenging	Ono et al. (2006)
		Antiobesity, Antihypolipidemic	You et al. (2014)
20	Plumule of ripe seed	Nervous maladies, insomnia, elevated fevers with restlessness and hypertension	Nguyen (1999)
21	Seed, rhizome	Anti-inflammatory	Mukherjee et al. (1997), Lin et al. (2006)
		Immunomodulatory	Mukherjee et al. (2010b)
22	Seed, leaves	Hepatoprotective	Huang et al. (2010b)
		Antiviral	Kashiwada et al. (2005), Kuo et al. (2005)
23	Plant extract	Anti-hyperlipidemic activity	Subasini et al. (2014)

Source: Modified from Sheikh SA (2014): Ethno-medicinal uses and pharmacological activities of lotus (*Nelumbo nucifera*). *Journal of Medicinal Plants Studies* 2(6): 42–46

and should be advanced for human clinical trials. Finally, there is urgent need for conservation of lotus plant as its habitat is getting disturbed, threatened, and polluted because of various anthropogenic activities.

References

Anonymous (1966) The wealth of India. A dictionary of Indian raw materials and industrial products. Council of Scientific Industrial Research, New Delhi

Anonymous (1982) Pharmacognosy of indigenous drugs vol. 2. Central Council for Research in Ayurveda and Siddha, New Delhi, p 806

Anonymous (1992) The wealth of India. A dictionary of Indian raw materials and industrial products, vol III, 2nd edn. Council of Scientific Industrial Research, New Delhi, pp 336–354

Arjun P, Saranya Sivan PS, Mohana Priya S, Krishnamoorthy M, Balasubramanian K (2012) Phytochemical analysis and anticancer activity of Nelumbo nucifera Gaertn extracts. J Acad Indus Res 1(2):81–85

Bera S, Bhattacharya S, Pandey JN, Biswas M (2011) Thin layer chromatographic profiling and evaluation of analgesic activity of Nelumbo nucifera leaf extracts in Swiss mice. J Adv Pharm Educ Res (JAPER) 1(6):259–265

Bi Y, Yang G, Li H, Zhang G, Guo Z (2006) Characterization of the chemical composition of Lotus plumele oil. J Agric and Food Chem 54(20):7672–7677. https://doi.org/10.1021/jf0607011

Brindha B, Arthi D (2010a) Antimicrobial activity of white and pink Nelumbo nucifera Gaertn flowers. Asian J Pharm Health Care (AJPRHC) 2(2):147–155

Brindha D, Arthi D (2010b) Antiplatelet activity of white and pink Nelumbo nucifera Gaertn Flowers. Br J of Pharmaceut Sci 46(3):579–583. https://doi.org/10.1590/S1984-82502010000300023

Chakravarthi PV, Gopakumar N (2009) Evaluation of analgesic activity of Lotus seeds (Nelumbo nucifera) in albino rats. Vet World 2(9):355–357

Chatterjee A, Pakrashi SC (1991) The treatise on Indian medicinal plants, vol I, 1st edn. Publication and Information Directorate, New Delhi, pp 94–96

Chauhan A, Agarwal M (2009) Pharmacological evaluation for the antifertility effect of the ethanolic seed extract of Nelumbo nucifera (Sacred Lotus). Pharmacology online 2(1):636–643

Chen Y, Fan GR, Wu HL, Wu YT, Mitchell A (2007) Separation, identification and rapid determination of liensine, isoliensinine and neferine from embryo of the seed of Nelumbo nucifera Gaertn. by liquid chromatography coupled to diode array detector and tandem mass spectrometry. J Pharm Biomed Anal 43(1):99–104

Chen S, Wu B, Fang J, Liu Y, Zhang H, Fang L, Le G, Li S (2012) Analysis of flavonoids from lotus (Nelumbo nucifera) leaves using high performance liquid chromatography/photodiode array detector tandem electrospray ionization mass spectrometry and an extraction method optimized by orthogonal design. J Chromatogr A 1227:145–153

Chen S, Xiang Y, Deng J, Liu YL, Li SH (2013) Simultaneous analysis of anthocyanin and non-anthocyanin flavonoid in various tissues of different lotus (Nelumbo) cultivars by HPLC-DAD-ESI-MSn. PLoS One 8(4):1–13

Cho EJ, Yokozawa T, Rhyu DY, Kim SC, Shibahara N, Park JC (2003) Study on the inhibitory effects of Korean medicinal plants and their main compounds on the 1, 1-diphenyl-2-picrylhydrazyl radical. Phytomedicine 10:544–551

Choe JH, Jang A, Lee ES, Choi JH, Choi YS, Han DJ, Kim HY, Lee MA, Shim SY, Kim CJ (2011) Oxidative and color stability of cooked ground pork containing lotus leaf (Nelumbo Nucifera) and Barley Leaf (Hordeum Vulgare) powder during refrigerated storage. Meat Sci 87:12–18. https://doi.org/10.1016/j.meatsci.2010.08.011

Choi YS, Choi JH, Kim HY, Kim HW, Lee MA, Chung HJ, Lee SK, Kim CJ (2011) Effect of lotus (Nelumbo nucifera) leaf powder on the quality characteristics of chicken patties in refrigerated storage. Korean J Food Sci Anim Resour 31(1):9–18

Chopra RN (1958) Indigenous drugs of India, 2nd edn. U N Dhur and Sons Pvt., Calcutta, p 679

Chopra RN, Nayara SL, Chopra IC (1956) Glossary of Indian medicinal plants. Council of Scientific and Industrial Research, New Delhi, p 174

Chu P, Chen HH, Zhou YL, Li Y, Ding Y, Jiang LW, Tsang EWT, Wu KQ, Huang SZ (2012) Proteomic and functional analyses of Nelumbo nucifera annexins involved in seed thermotolerance and germination vigor. Planta 235(6):1271–1288

Das S, Ray B, Ghosal PK (1992) Structural studies of a polysaccharide from the seeds of Nelumbo nucifera. Carbohydr Res 224:331–335

Deepa PK, Usha PTA, Chandrasekharan Nair AM, Prasannakumari KT (2009) Antipyretic activity of seeds from red and white type of lotus (Nelumbo nucifera) in Albino rat. Vet World 2 (6):213–214

Deng J, Chen S, Yin XJ, Wang K, Liu YL, Li SH, Yang PF (2013) Systematic qualitative and quantitative assessment of anthocyanins, flavones and flavonols in the petals of 108 lotus (Nelumbo nucifera) cultivars. Food Chem 139(1–4):307–312

Devkota SR, Paudel KR, Sharma K et al (2015) Investigation of antioxidant and anti-inflammatory activity of roots of Rumex nepalensis. World J Pharm Pharm Sci (WJPPS) 4(3):582–594

Dey TB, Chakraborty S, Jain KK, Sharma A, Kuhad RC (2016) Antioxidant phenolics and their microbial production by submerged and solid state fermentation process: a review. Trends Food Sci Technol 53:60–74

Du H, You JS, Zhao X, Park JY, Kim SH, Chang KJ (2010) Antiobesity and hypolipidemic effects of lotus leaf hot water extract with taurine supplementation in rats fed a high fat diet. J Biomed Sci 17(1):S42–S47. https://doi.org/10.1186/1423-0127-17-S1-S39

Duan Y, Zhang H, Xu F, Xie B, Yang X, Wang Y, Yan Y (2004) Inhibition effect of procyanidins from lotus seedpod on mouse B16 melanoma in vivo and in vitro. Food Chem 122:84–91

Duan Y, Zhang H, Xie B, Yan Y, Li J, Xu F, Qin Y (2010) Whole body radioprotective activity of an acetone-water extract from the seedpod of Nelumbo nucifera Gaertn. Seedpod Food Chem Toxicol 48(12):3374–3338

Duke JA, Bogenschutz-Godwin MJ, duCellier J, Duke AK (2002) Handbook of medicinal herbs. CRC Press, Boca Raton, p 595

Durairaj B, Dorai A (2014) Free radical scavenging potential of Nelumbo nucifera Gaertn flowers (white and pink). Int J Nat Sci Res 2(8):133–146

Feng CY, Li SS, Yin DD, Zhang HJ, Tian DK, Wu Q, Wang LJ, Su S, Wang LS (2016) Rapid determination of flavonoids in plumules of sacred lotus cultivars and assessment if their antioxidant activities. Ind Crop Prod 87:96–104

Follett J, Douglas J (2003) Lotus root: production in Asia and potential for New Zealand. In Combined proceedings international plant propagators society, vol 53, pp 79–83

Furukawa H (1966) Studies on the alkaloids of Nelumbo nucifera Gaertn. NMR spectra of Liensinine type alkaloids. J Pharm Soc Jpn 86(10):883–886

Furukawa H, Yang TH, Lin TJ (1965) On the alkaloids of Nelumbo nucifera Gaertn. XI. Alkaloids of loti embryo. 4. Structure of lotusine, a new water soluble quaternary base. J Pharm Soc Jpn 85 (5):472–475

Gong YS, Liu LG, Xie BJ, Liao YC, Yang EL, Sun ZD (2008) Ameliorative effects of lotus seedpod proanthocyanidins on cognitive deficits and oxidative damage in senescence-accelerated mice. Behav Brain Res 194:100–107

Goo HR, Choi JS, Na DH (2009) Simultaneous determination of quercetin and its glycosides from the leaves of Nelumbo nucifera by reversed-phase high-performance liquid chromatography. Arch Pharm Res 32(2):201–206. https://doi.org/10.1007/s12272-009-1136-y

Guo H (2009) Cultivation of lotus (Nelumbo nucifera Gaertn. ssp. nucifera) and its utilization in China. Genet Resour Crop Evol 56(3):323–330

Gutteridge JM, Halliwell B (2000) Free radicals and antioxidants in the year 2000-A historical look to the future. Ann N Y Acad Sci 899:136–147

Ham YK, Hwang KE, Song DH, Kim YJ, Shin DJ, Kim KI, Lee HJ, Kim NR, Kim CJ (2017) Lotus (Nelumbo nucifera) rhizome as an antioxidant dietary Fiber in cooked sausage: effects on physicochemical and sensory characteristics. Korean J Food Sci Anim Resour 37:219–227. https://doi.org/10.5851/kosfa.2017.37.2.219

Harborne JB (1998) Phytochemical methods, 3rd edn. Chapman & Hall, London

Harer WB (1985) Pharmacological and biological properties of the Egyptian lotus. J Am Res Cent Egypt (JARCE) 22:49–54

Horwitz W (2000) Official methods of analysis of AOAC international, 17th Ed., vol. 2. AOAC international, Maryland. Chapter 45: p5

Hu SY (2005) Food plants of China. The Chinese University Press, Hong Kong, New Territories, 844 pp

Hu M, Skibsted LH (2002) Antioxidative capacity of rhizome extract and rhizome knot extract of edible lotus (Nelumbo nuficera). Food Chem 76:327–333

Huang B, Ban XQ, He JS, Tong J, Tian J, Wang YW (2010a) Comparative analysis of essential oil components and antioxidant activity of extracts of Nelumbo nucifera Gaertn from various areas of China. J Agric Food Chem 58(1):441–448

Huang B, Ban XQ, He JS, Tong J, Tian J, Wang YW (2010b) Hepatoprotective and antioxidant activity of ethanolic extracts of edible lotus (Nelumbo nucifera Gaertn.) leaves. Food Chem 120 (3):873–878

Huang B, He J, Ban X, Zeng H, Yao X, Wang Y (2011) Antioxidant activity of bovine and porcine meat treated with extracts from edible lotus (Nelumbo nucifera) rhizome knot and leaf. Meat Sci 87:46–53

Huralikuppi JC, Christopher AB, Stephen P (1991) Antidiabetic effect of Nelumbo nucifera (Gaertn): Part I preliminary studies in rabbits. Phytother Res 5:54–58

Hwang D, Charchoghlyan H, Lee JS, Kim M (2015) Bioactive compounds and antioxidant activities of the Korean lotus leaf (Nelumbo nucifera) condiment: volatile and nonvolatile metabolite profiling during fermentation. Int J Food Sci Tech (IJFST) 50:1988–1995

Hyun AJ, Jung EK, Hae YC, Jae SC (2003) Antioxidant principles of Nelumbo nucifera stamens. Arch Pharm Res 26:279–285

Hyun SK, Jung YJ, Chung HY, Jung HA, Choi JS (2006) Isorhamnetin glycosides with free radical and ONOO- scavenging activities from the stamens of Nelumbo nucifera Gaertn. Arch Pharm Res 29(4):287–292

Ibrahim N, Eraqy EW (1996) Protein content and amino acid composition of Nelumbo nucifera Gaertn seeds and its evaluation as hypoglycemic agent. Egypt J Pharm Sci 37:635–641

Indrayan AK, Sharma SD, Kumar DN, Kumar M (2005) Determination of nutritive value and analysis of mineral elements for some medicinally valued plants from Uttaranchal. Curr Sci 89:1252–1255

Jiqu X, Shuang R, Bijun X, Zhida S, Li Z, Hailei W, Ping Y, Liping H, Liegang L (2010) Procyanidins extracted from the lotus seedpod ameliorate age-related antioxidant deficit in aged rats. J Gerontol 65:236–241

Jung HA, Kim JE, Chung HY, Choi JS (2003) Antioxidant principles of Nelumbo nucifera Gaertn stamens. Arch Pharm Res 26(4):279–285

Jung IC, Park HS, Choi YJ, Park SS, Kim MJ, Park KS (2011) The effect of adding lotus root and leaf powder on the quality characteristics of cooked pork patties. Korean J Food Cookery Sci 27:783–791. https://doi.org/10.9724/kfcs.2011.27.6.783

Karadag A, Ozcelik B, Saner S (2009) Review of methods to determine antioxidant capacities. Food Anal Method 2:41–60

Karki R, Jung MA, Kim KJ, Kim DW (2012) Inhibitory effect of Nelumbo nucifera (Gaertn.) on the development of atopic dermatitis-like skin lesions in NC/Nga mice. Evid Based Complement Alternat Med 2012:153568

Karki R, Jeon ER, Kim DW (2013) Nelumbo nucifera Gaertn leaf extract inhibits neointimal hyperplasia through modulation of smooth muscle cell proliferation and migration. Nutrition 29(1):268–275

Kashiwada Y, Aoshima A, Ikeshiro Y, Chen YP, Furukawa H, Itoigawa M, Fujioka T, Mihashi K, Cosentino LM, Morris SL, Lee KH (2005) Anti-HIV benzylisoquinoline alkaloids and flavonoids from the leaves of Nelumbo nucifera, and structure activity correlations with related alkaloids. Bioorg Med Chem 13(2):443–448

Khare CP (2004) Indian herbal remedies: rational western therapy, ayurvedic, and other traditional usage, Botany, 1st edn. Springer, New York, pp 326–327

Kim J, Kang M, Cho C, Chung H, Kang C, Parvez S et al (2006) Effects of Nelumbinis semen on contractile dysfunction in ischemic and reperfused rat heart. Arch Pharm Res 29:777–785

Kim T, Hj K, Sk C, Wy K, Baek H, Hy J, Kim BY, Kim D (2011) Nelumbo nucifera extracts as whitening and antiwrinkle cosmetic agent. Korean J Chem Eng 28(2):424–427

Kirtikar KR, Basu BD (1933) In: Blatter E, Caius JF, Mhaskar KS (eds) Indian Medicinal Plants I-IV. India, Lalit Mohan Basu, Allahabad

Kirtikar KR, Basu BD (1975) Indian medicinal plants, 2nd edn. International Book Distributors, New Delhi, pp 116–120

Krishnamoorthy G, Chellappan DR, Joseph J, Ravindhran D, Shabi MM, Uthrapathy S et al (2009) Antioxidant activity of Nelumbo nucifera (Gaertn) flowers in isolated perfused rat kidney. Rev Bras Farmacogn 19(1b):224–229

Kubo N, Hirai M, Kaneko A, Tanaka D, Kasumi K (2009) Development and characterization of simple sequence repeat (SSR) markers in the water lotus (Nelumbo nucifera). Aquat Bot 90:191–194

Ku-Lee H, Mun-Choi Y, Ouk-Noh D, Joo-Suh H (2005) Antioxidant effect of Korean traditional Lotus liquor (Yunyupju). Int J Food Sci Technol 40:709–787

Kunitomo J, Yoshikawa Y, Tanaka S, Imori Y, Isoi K, Masada Y, Hashimoto K, Inoue T (1973) Alkaloids of Nelumbo nucifera. Phytochemistry 12(3):699–701

Kuo YC, Lin YL, Liu CP, Tsai WJ (2005) Herpes simplex virus type 1 propagation in HeLa cells interrupted by Nelumbo nucifera. J Biomed Sci 12(6):1021–1034

Kupchan SM, Dasgupta B, Fujita E, King ML (1963) The alkaloids of American lotus, Nelumbo lutea. Tetrahedron 19:227–232

La Cour B, Molgaard P, Yi Z (1995) Traditional Chinese medicine in treatment of hyperlipidaemia. J Ethnopharmacol 46(2):125–129

Lee MW, Kim JS, Cho SM, Kim JH, Lee JS (2001) Antidiabetic constituent from the nodes of lotus rhizome (Nelumbo nucifera Gaertn). Nat Prod Sci 7:107–109

Lee HK, Choi YM, Noh DO, Suh HJ (2005) Antioxidant effect of Korean traditional lotus liquor (Yunyupju). Int J Food Sci Technol 40(7):709–715

Lee H, Kim Y, Kim HJ et al (2012) Herbal formula, PM014, attenuates lung inflammation in a murine model of chronic obstructive pulmonary disease. Evid Based Complement Alternat Med 2012:769830

Lim TK (2016) Edible medicinal and non-medicinal plants: volume 11, modified stems, roots, bulbs. Springer, Heidelberg

Lim SS, Jung YJ, Hyun SK, Lee YS, Choi JS (2006) Rat lens aldose reductase inhibitory constituents of Nelumbo nucifera Gaertn stamens. Phytother Res 20(10):825–830

Lin JY, Wu AR, Liu CJ, Lai YS (2006) Suppressive effects of lotus plumule (Nelumbo nucifera Geartn) supplementation on LPS-induced systemic inflammation in a BALB/c mouse model. J Food Drug Anal 14(3):273–278

Lin RJ, Wu MH, Ma YH, Chung LY, Chen CY, Yen CM (2014) Anthelmintic activities of Aporphine from Nelumbo nucifera Gaertn. cv. Rosa-plena against Hymenolepis nana. Int J Mol Sci 15:3624–3639

Ling ZQ, Xie BJ, Yang EL (2005) Isolation, characterization and determination of antioxidative activity of oligomeric proanthocyanidins from the seedpod of Nelumbo nucifera Gaertn. J Agric Food Chem 53(7):2441–2445

Liu CP, Tsai WJ, Lin YL, Liao JF, Chen CF, Kuo YC (2004) The extracts from Nelumbo nucifera Gaertn suppress cell cycle progression, cytokine genes expression, and cell proliferation in human peripheral blood mononuclear cells. Life Sci 75(6):699–716

Liu CP, Tsai WJ, Lin YL, Liao JF, Chen CF, Kuo YC (2006) Inhibition of (S)-armepavine from Nelumbo nucifera on autoimmune disease of MRL/MpJ-lpr/lpr mice. Eur J Pharmacol 531 (1–3):270–279

Liu S, Wang B, Li XZ, Qi LF, Liang YZ (2009) Preparative separation and purification of liensinine, isoliensinine and neferine from seed embryo of Nelumbo nucifera Gaertn using high-speed counter-current chromatography. J Sep Sci 32(14):2476–2481

Liu C, Kao C, Wu H, Li W, Huang C, Li H, Chen C (2014) Antioxidant and anticancer aporphine alkaloids from the leaves of Nelumbo nucifera Gaertn. cv. Rosa-plena. Molecules 19 (11):17829–17838

Lopez-Alarcon C, Denicola A (2013) Evaluating the antioxidant capacity of natural products: a review on chemical and cellular-based assays. Anal Chim Acta 763:1–10

Mani SS, Subramanian IP, Pillai SS, Muthusamy K (2010) Evaluation of hypoglycemic activity of inorganic constituents in Nelumbo nucifera seeds on streptozotocin-induced diabetes in rats. Biol Trace Elem Res 138(1–3):226–237

Mehra KL, Kanodia KC, Srivastava RN (1975) Folk uses of plants for adornment in India. Econ Bot 29(1):39–46

Mehta NR, Ekta P, Pragnesh P, Patani V, Shah B (2013) Nelumbo nucifera (Lotus): a review on ethanobotany, phytochemistry and pharmacology. Indian J Pharm Biol Res (IJPBR) 1 (4):152–167

Ming R, VanBuren R, Liu Y, Yang M, Han Y, Li LT et al (2013) Genome of the long-living sacred lotus (Nelumbo nucifera Gaertn.). Genome Biol 14:R41

Moure A, Cruz JM, Franco D, Dominguez JM, Sineiro J, Dominguez H et al (2001) Natural antioxidants from residual sources. Food Chem 72:145–171

Mukherjee PK, Balasubramanian R, Saha K, Saha BP, Lal P (1995a) Hypoglycemic activity of Nelumbo nucifera rhizome (methanolic extract) in streptozotocin induced diabetic rats. Phytother Res 9:522–524

Mukherjee PK, Giri SN, Saha K, Pal M, Saha BP (1995b) Isolation, estimation and characterization of starch from rhizomes of Nelumbo nucifera Gaertn (Fam. Nymphaeaceae). Ind Drugs 32:392–397

Mukherjee PK, Balasubramanian R, Saha K, Saha BP, Lal P (1996a) A review of Nelumbo nucifera Gaertn. Anc Sci Life 15:268–276

Mukherjee PK, Balasubramanian R, Saha K, Saha BP, Lal P (1996b) A review of Nelumbo nucifera Gaertn. rhizome extract. J Ethnopharmacol 54:63–67

Mukherjee PK, Das J, Saha K, Pal M, Saha BP (1996c) Diuretic activity of the rhizomes of Nelumbo nucifera Gaertn (Fam. Nymphaeaceae). Phytother Res 10:424–425

Mukherjee PK, Saha K, Balasubramanian R, Pal M, Saha BP (1996d) Studies on psychopharmacological effects of Nelumbo nucifera Gaertn. rhizome extract. J Ethnopharmacol 54(2):63–67

Mukherjee PK, Das J, Saha K, Giri SN, Pal M, Saha BP (1996e) Antipyretic activity of Nelumbo nucifera rhizome extract. Ind J Exp Biol 34(3):275–276

Mukherjee PK, Balasubramanian R, Saha K, Saha BP, Lal P (1997a) Effect of Nelumbo nucifera rhizomes extract on blood sugar level in rats. J Ethnopharmacol 58:207–213

Mukherjee PK, Balasubramanian R, Saha K, Saha BP, Lal P (1997b) A review of Nelumbo nucifera. Planta Med 63:367–369

Mukherjee PK, Saha K, Das J, Pal M, Saha BP (1997c) Studies on the anti-inflammatory activity of rhizomes of Nelumbo nucifera. Planta Med 63(4):367–369

Mukherjee PK, Mukherjee D, Maji AK, Rai S, Heinrich M (2009) The sacred lotus (Nelumbo nucifera) – phytochemical and therapeutic profile. J Pharm Pharmacol 61(4):407–422

Mukherjee D, Khatua TN, Venkatesh P, Saha BP, Mukherjee PK (2010a) Immunomodulatory potential of rhizome and seed extracts of Nelumbo nucifera Gaertn. J Ethnopharmacol 128:490–494

Mukherjee PKPK, Balasubramanian R, Saha K, Saha BP, Lal P (2010b) A review of Nelumbo nucifera Gaertn. J Ethnopharmacol 128:490–494

Mutreja A, Agarwal M, Kushwaha S, Chauhan A (2008) Effect of Nelumbo nucifera seeds on the reproductive organs of female rats. Iran J Reprod Med 6(1):7–11

Nadkarni AK (1954) Indian Materia Medica. Vol. 1 (3 rd edn). Popular Book Depot, Bombay

Nagarajan S, Nair AGR, Ramkrishnan S, Subramanian SS (1966) Chemical examination of the flowers of Nelumbium speciosum willd. Curr Sci 35(7):176

Nguyen Q (1999) Lotus a new crop for Australian horticulture. IHD Access Asia Newslett 2:1–5. http://www.nre.vic.gov.au/trade/asiaveg/nlaf-04c.htm
Ohkoshi E, Miyazaki H, Shindo K, Watanabe H, Yoshida A, Yajima H (2007) Constituents from the leaves of Nelumbo nucifera stimulate lipolysis in the white adipose tissue of mice. Planta Med 73(12):1255–1259
Onishi E, Yamada K, Yamada T, Kaji K, Inoue H, Seyama Y, Yamashita S (1984) Comparative effects of crude drugs on serum lipids. Chem Pharm Bull 32(2):646–650
Ono Y, Hattori E, Fukaya Y, Imai S, Ohizumi Y (2006) Anti-obesity effect of Nelumbo nucifera Gaertn leaves extract in mice and rats. J Ethnopharmacol 106(2):238–244
Patel KK, Toppo FA, Singour PK, Chaurasiya PK, Rajak H, Pawar RS (2012) Phytochemical and pharmacological investigations on the aerial parts of Nelumbo nucifera Gaertn. For hematopoietic activity. Indian J Nat Prod Resour 3(4):512–517
Phillips R, Rix M (1995) Vegetables, vol IV, 3rd edn. Macmillan Reference Books, London, pp 736–796
Phonkot N, Aromdee C (2006) Determination of total flavonoids, total carotenes and antioxidant activity of 4 varieties of lotus stamens. Isan J Pharm Sci 2(2):136
Phonkot N, Wangsomnuk PP, Aromdee C (2010) High-performance liquid chromatographic determination of β-carotene content in four varieties of lotus stamens. Songklanakarin J Sci Technol 32(4):373–377
Qi A, Zhou D (2013) Lotus seed epicarp extract as potential antioxidant and anti-obesity additive in Chinese Cantonese sausage. Meat Sci 93:257–262
Qian JQ (2002) Cardiovascular pharmacological effects of bisbenzylisoquinoline alkaloid derivatives. Acta Pharmacol Sin 23(12):1086–1092
Raghunath K, Mitra R (2005) Pharmacognosy of indigenous drugs, vol 2. Central Council for Research in Ayurveda and Siddha, India, p 806
Rai S, Wahile A, Mukherjee K, Saha BP, Mukherjee PK (2006) Antioxidant activity of Nelumbo nucifera (sacred lotus) seeds. J Ethnopharmacol 104(3):322–327
Rakesh PD, Sekar S, Kumar KLS (2011) A comparative study on the antidiabetic effect of Nelumbo nucifera and glimepiride in streptozotocin induced diabetic rats. Int J Pharm Bio Sci 2(2):63–69
Rao GMM, Pushpangadan P, Shirwaikar A (2005) Hepatoprotective activity of Nelumbo nucifera Geartn. flower an ethanopharmacological study. Acta Pharm Ceutica Turcica 47:79–88
Saengkhae C, Arunnopparat W, Sungkhajorn P (2008) Antioxidant activity of Nelumbo nucifera Gaertn on oxidative stress-induced erythrocyte hemolysis in hypertensive and normotensive rats. J Physiol Sci 20(2):70–78
Sayre J (2004) Native plants: propagation protocol for American lotus (Nelumbo lutea Willd). Native Plants J 15:14–17
Sheikh SA (2014) Ethno-medicinal uses and pharmacological activities of lotus (Nelumbo nucifera). J Med Plants Stud 2(6):42–46
Shen-Miller J (2002) Sacred lotus, the long-living fruits of China Antique. Seed Sci Res 12 (3):131–143
Shen-Miller J, Schopf JW, Harbottle G, Cao RJ, Ouyang S, Zhou KS, Southon JR, Liu GH (2002) Long-living lotus: germination and soil g-irradiation of centuries-old fruits, and cultivation, growth, and phenotypic abnormalities of offspring. Am J Bot 89:236–247
Shoji N, Umeyama A, Saito N, Iuchi A, Takemoto T, Kajiwara A et al (1987) Asimilobine and liridine, serotonergic receptor antagonists from Nelumbo nucifera. Nat Prod 50:773–774
Shukla S, Lee JS, Park J, Hwang DJ, Park JH, Kim M (2016) Quantitative analysis of functional components from Nelumbo nucifera root-fermented broth with antioxidant and tyrosinase inhibitory effects. J Food Biochem 40:248–259
Sinha S, Mukherjee PK, Mukherjee K, Pal M, Mandal SC, Saha BP (2000) Evaluation of antipyretic potential of Nelumbo nucifera stalk extract. Phytother Res 14:272–274
Sohn DH, Kim YC, Oh SH, Park EJ, Li X, Lee BH (2003) Hepatoprotective and free radical-scavenging effects of Nelumbo nucifera. Phytomedicine 10:165–169
Sridhar KR, Bhat R (2007) Lotus – a potential nutraceutical source. J Agric Technol 3:143–155

Subasini U, Thenmozhi S, Venkateswaran V, Pavani P, Diwedi S, Rajamanickam GV (2014) Phytochemical analysis and anti hyperlipidemic activity of Nelumbo nucifera in male Wistar rats. Int J Pharm Teach Pract (IJPTP) 5(1):935–940

Tomita M, Watanabe Y, Furukawa H (1961) On the alkaloids of Nelumbo nucifera Gaertn. IV. Isolation of dl-armepavine. Jpn J Pharmacol Yakugaku Zasshi 81(11):1644–1647

Tomita M, Furukawa H, Yang TH, Lin TJ (1965) On the alkaloids of Nelumbo nucifera Gaertn Gaertn. VIII. Studies on the alkaloids of loti embryo. (1). Structure of isoliensinine, a new biscoclaurine type alkaloid. Chem Pharm Bull 13(1):39–43

Toyoda K (1966) Glutathione in the seed of Nelumbo nucifera. Chem Abstr 65:10959

United States Department of Agriculture Agricultural Research Service (2019) Food Data Central: Food and Nutrient Database for Dietary studies with standard reference legacy release-169250, 16859. Retrieved 10-03-2020. www. fdc.nal.usda.gov

Ushimaru T, Kanematsu S, Katayama M, Tsuji H (2000) Antioxidative enzymes in seedlings of Nelumbo nucifera germinated under water. Physiol Plant 112:39–46

Vahitha Bi SM, Banumathi V, Anbu J, Anjana A, Kumar MP (2012) Aphrodisiac activity of venthamarai magarantha chooranam (stamens of Nelumbo nucifera white variety) on healthy wister albino rats. Int J Life Sci Pharma Res 2:44–50

Varshney CK, Rzóska J (1976) Aquatic weeds in South East Asia, 1st edn. Springer, New Delhi, p 39

Venkatesh B, Dorai A (2011) Antibacterial and antioxidant potential of white and pink Nelumbo nucifera Gaertn flowers. Int Conf Biosci Bioche Bioinform 5:213–217

Wang YW (2010) Hepatoprotective and antioxidant activity of ethanolic extracts of edible lotus (Nelumbo nucifera Gaertn.) leaves. Food Chem 120:873–878

Wang Q, Zhang X (2005) Lotus flower cultivars in China. China Forestry Publishing House, Beijing, (ISBN:7-5038-3867-1)

Wang JL, Hu XM, Yin WH, Cai HS (1991) Studies on alkaloids of Plumula Nelumbinis. Zhongguo Zhong Yao Za Zhi (J Chin Mat Med) 16(11):673–675

Williamson PS, Schneider EL (1993) Nelumbonaceae. In: Kubitzki K (ed) The families and genera of vascular plants. Springer, Berlin, pp 470–473

Wong CF (1987) Origin and historical record of Nelumbo nucifera, Eds. China Institute of Botany, China lotus, Beijing, Academia Sinica, Science Publishers, pp 1–8

Wu MJ, Wang L, Weng CY, Yen JH (2003) Antioxidant activity of methanol extract of the lotus leaf (Nelumbo nucifera Gaertn). Am J Chin Med 31:687–698

Wu SH, Sun CR, Cao XJ, Zhou H, Hong Z, Pan YJ (2004) Preparative counter-current chromatography isolation of liensinine and its analogues from embryo of the seed of Nelumbo nucifera GAERTN. Using upright coil planet centrifuge with four multilayer coils connected in series. J Chromatogr A 1041(1–2):153–162

Wu YB, Zheng LJ, Yi J, Wu JG, Chen TQ, Wu JZ (2013) Quantitative and chemical fingerprint analysis for the quality evaluation of Receptaculum Nelumbinis by RP-HPLC coupled with hierarchical clustering analysis. Int J Mol Sci 14(1):1999–2010

Xiao JH, Zhang JH, Chen HL, Feng XL, Wang JL (2005) Inhibitory effect of isoliensinine on bleomycin induced pulmonary fibrosis in mice. Planta Med 71:225–230

Yang DM, Wang QS, Ke LQ, Jiang JM, Ying TJ (2007) Antioxidant activities of various extracts of lotus (Nelumbo nuficera Gaertn) rhizome. Asia Pac J Clin Nutr 16(Suppl 1):158–163

Yang RZ, Wei XL, Gao FF, Wang LS, Zhang HJ, Xu YJ, Li CH, Ge YX, Zhang JJ, Zhang J (2009) Simultaneous analysis of anthocyanins and flavonols in petals of lotus (Nelumbo) cultivars by high-performance liquid chromatography-photodiode array detection/electrospray ionization mass spectrometry. J Chromatogr A 1216:106–112

Yang M, Han Y, VanBuren R, Ming R, Xu L, Han Y et al (2012) Genetic linkage maps for Asian and American lotus constructed using novel SSR markers derived from the genome of sequenced cultivar. BMC Genomics 13:653

Yen GC, Duh PD, Su HJ (2005) Antioxidant properties of lotus seed and its effect on DNA damage in human lymphocytes. Food Chem 89:379–385

Yen GC, Duh PD, Yeha CT, Wu CH (2006) Scavenging effects of lotus seed extracts on reactive nitrogen species. Food Chem 94(4):596–602

You PZ (1998) Chinese Materia Medica: chemistry, pharmacology and applications. Harwood Academic Publishers, Amsterdam, ISBN:90-5702-285

You JS, Lee YJ, Kim KS, Kim SH, Chang KJ (2014) Antiobesity and hypolipidaemic effects of Nelumbo nucifera Gaertn seed ethanol extract in human pre-adipocytes and rats fed a high-fat diet. J Sci Food Agric 94(3):568–575

Youn UJ, Lee JH, Lee YJ, Nam JW, Bae H, Seo EK (2010) Regulation of the 5-HT3A receptor-mediated current by alkyl 4-hydroxybenzoates isolated from the seeds of Nelumbo nucifera. Chem Biodivers 7(9):2296–2302

Yu J, Hu WS (1997) Effects of neferine on platelet aggregation in rabbits. Acta Pharm Sin 32:1–4

Zhang XH, Zhang B, Gong PL, Zeng FD (2004) Protective effect of procyanidins from the seedpod of the lotus on myocardial ischemia and its mechanisms. Yao Xue Xue Bao 39:747–750

Zhang L, Tu ZC, Wang H et al (2015) Response surface optimization and physicochemical properties of polysaccharides from Nelumbo nucifera leaves. Int J Biol Macromol 74:103–110. https://doi.org/10.1016/j.ijbiomac.2014.11.020

Zheng LJ, Wu YB, Wu JG, Tan CJ, Yi J, Chen TQ, Wu JZ (2012) Antioxidant activity of lotus (Nelumbo nucifera Gaertn.) receptacles of eleven cultivars grown in China. J Med Plants Res 6 (10):1902–1911. https://doi.org/10.5897/JMPR11.1373

Zhou T, Luo D, Li X, Luo Y (2009) Hypoglycemic and hypolipidemic effects of flavonoids from lotus (Nelumbo nucifera Gaertn) leaf in diabetic mice. J Med Plant Res 3(4):290–300

Zhu M, Liu T, Zhang C, Guo M (2017) Flavonoids of Lotus (Nelumbo nucifera) Seed embryos and their antioxidant potential. J Food Sci 82(8):1834–1841. https://doi.org/10.1111/1750-3841.13784

Zoecklin BW, Fugelsang KC, Gump BH, Nury FS (1995) Wine analysis and production. Chapman and Hall, New York, p 621