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CENTELLA ASIATICA IN AYURVEDA AND MODERN MEDICINE: AN INSIGHT INTO ITS BIOACTIVE COMPOUNDS AND CLINICAL PROSPECTS

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ABSTRACT

Indian Ayurvedic medicine is widely used to treat a wide range of illnesses. One of the key herbs for reviving nerve and brain cells is *Centella asiatica*, often known as Gotu kola, ***Centella asiatica*** is known for its valuable medicinal properties which highlight its potential application in the pharmaceutical industry and in traditional medicine, *Centella asiatica* is well-known for its many uses, including the treatment of lupus, skin maladies, leprosy, fever, gastrointestinal problems, mental illnesses, neurodegenerative diseases, and improved cognitive abilities. Its chemical components have numerous therapeutic uses in the fields of antibacterial, anti-inflammatory, anticancer, neuroprotective, antioxidant, and wound healing properties, and the aerial parts and roots are used for medical purposes. Numerous applications have been scientifically evaluated, and the bioactive components have been confirmed., which is thought to improve memory, longevity, and intelligence. Triterpenoid saponins, such as Asiatic acid, madecassoside, *Centelloside*, and *Asiaticoside*, are significant bioactive substances. It has antiviral, antibacterial, antitumor, and antileprotic properties. In this paper we have focus on the Ayurvedic Properties of the *Centella asiatica*.

KEY WORDS: Medicinal Properties, *C. asiatica*, *Gotu kola*, Natural compounds, Ayurvedic properties, Terpenoids, Flavonoids

INTRODUCTION

Centella asiatica has a long history of usage in Eastern traditional medicine and is becoming increasingly well-known in Western countries. The Apiaceae (*Umbelliferae)* family includes this perennial herb, which grows well in warm, humid climes in places like China, America, Australia, Malaysia, and South Africa. The French Pharmacopoeia, Indian Ayurvedic systems, and Chinese Pharmacopoeia have all reported on its therapeutic qualities.[1] *Gotu kola*, the more popular common name for this herbaceous plant, belongs to the *Mackinlayaceae* family (Table 1). The other colloquial names for the plant are Thankuni (Bengali), Mandookaparni (Hindi), Pegaga (Malay), Kodagam (Malayalam), Gotukola (Sinhalese), Vallarai (Tamil), and Bekaparanamu (Telugu), indicating its extensive presence and importance in traditional medicine.[2]

As traditional remedies, it has been used by Ayurvedic, Chinese, and Sri Lankan practitioners to treat a variety of ailments, such as lupus, skin conditions, leprosy, fever, gastrointestinal problems, mental disorders, neurodegenerative conditions, and to improve cognitive abilities.[3] *C. asiatica* cures ulcers and leprosy, protects asthma, enhances cognition, and has antibacterial and anticancer properties. *C. asiatica* may have prebiotic and antioxidant properties when consumed as a beverage. The potential for creating nutraceutical goods may be favorable.[4] *C. asiatica* is mainly referred to as a "Brain food" in India because it is one of the main herbs used to treat skin conditions, mend wounds, and revitalize nerves and brain cells to memory-enhancing qualities.[5] It has successfully proved in animal models to have neurotoxic effects that increase memory and stimuli reflux, and it has been shown to enhance the general mental ability of children with intellectual disabilities.[6,7]

In addition to its therapeutic benefits, *C. asiatica* is a hyper-accumulator of heavy metals that is rarely documented in the literature; through its roots, it easily

absorbs metals that are dissolved in water and those that are in ionic form.[8]

Table 1: Taxonomy of *Centella asiatica*

Plantae	
Division	Tracheophyta
Subdivision	Spermatophyta
Class	Magnoliopsida
Order	Apiales
Family	Apiaceae (Umbelliferea)
Genus	*Centella*
Species	*asiatica*

In addition to some temperate regions of China, Korea, Japan, and Taiwan, the perennial plant *C. asiatica* Urban flourishes in swampy areas of tropical and subtropical regions of India, Southeast Asia, and Malaysia.[9] The herb holds lot of pentacyclic triterpenoids (C30), the most bioactive of which are madecassoside (bioactive compound), asiaticoside, and its aglycones, madecassic acid and asiatic acid.[10] Sesquiterpenes (C15) and monoterpenes (C10), such as α-humulene, ß-caryophyllene, myrcene, bicyclogermacrene, and germacrene-D, are abundant in plant essential oils.[11] Chlorogenic acids, isomeric dicaffeolyl esters, and flavonoids like epicatechin, catechin, kaempferol, and quercetin are among the other components found in the aerial part of *C. asiatica*[12] for Alzheimer's, and the medications used to treat the condition are not highly effective. The number of Alzheimer's cases is predicted to drop significantly over the next 50 years if pharmaceutical interventions might delay the onset or course of the illness. The most effective source of medication research leads has been found in Ayurvedic medicinal plants, and more than a hundred novel compounds are currently undergoing clinical development.

I. ACTIVE COMPOUNDS FOUND IN *C. asiatica.*

According to research investigations, *C. asiatica* has a large number of secondary metabolites, primarily triterpenoids and phenolic compounds, which support the herb's medicinal use as well as other functional qualities.

To boost the extract yield and the size of the bioactivity, it is crucial to use a proper extraction technique. Furthermore, since different solvents have varied affinities for various chemicals, selecting the right solvent is also crucial to boosting the effectiveness of *the C. asiatica* extract. Nonpolar extracts remove nonpolar chemicals from the herb, while polar solvents work well with polar molecules. Moreover, an efficient and secure extraction procedure depends on the stability of the designated components and the solvent's toxicity.[13] Now, studies are currently being done on the extraction of bioactive compounds from plant material using green solvents, like aqueous ethanol mixtures.

II. BIOACTIVE COMPOUNDS FOUND IN *C. asiatica.*

The phytochemical screening of the plant found alkaloids, flavonoids, saponins, phenols, steroids, glycosides, tannins, triterpenoids, and terpenoids (Table 2). Plants having bioactive secondary metabolites have been employed as natural treatments and are commonly given in recipes as crude pharmaceuticals. Alkaloids, both natural and synthetic, have been shown to have analgesic, antispasmodic, and bactericidal properties. Alkaloids have been shown to improve kidney function.[14] Many alkaloids have pharmacological properties. It has been used to treat malaria, relieve pain, and manage heart disease.[15] Flavonoids are known to have significant antibacterial action.[16]

Table 2: Bioactive compounds and their properties of the *C. asiatica.*

Class of Compound	**Bioactive Compound**	**Medicinal Properties**	**Reference**
Triterpenoid Saponins (Centelloids)	*Asiaticoside*	Wound healing, collagen synthesis, antibacterial, neuroprotective	[37] [40] [47]
	Madecassoside	Anti-inflammatory, antioxidant, skin healing, anti-aging	
	Asiatic Acid	Neuroprotective, anticancer, hepatoprotective, antioxidant	
	Madecassic Acid	Anti-inflammatory, wound healing, angiogenesis promoter	
Flavonoids	*Quercetin*	Antioxidant, anti-cancer, neuroprotective, cardioprotective	[18] [38]
	Kaempferol	Anti-inflammatory, circulatory health, anticancer	
	Rutin	Vascular health, anti-inflammatory, antioxidant	
Phenolic Acids	*Caffeic Acid*	Antioxidant, neuroprotective, anti-inflammatory	[19] [48]
	Chlorogenic Acid	Anti-diabetic, lipid-lowering, anti-inflammatory	
	Ferulic Acid	UV protection, anti-aging, antioxidant	
Sterols	*Stigmasterol*	Anti-inflammatory, cholesterol-lowering, immune-boosting	[12] [49]
	β-Sitosterol	Cardioprotective, cholesterol-lowering, anti-cancer	

Amino Acids	*Glutamic Acid*	Wound healing, nerve function support	[18] [21]
	Aspartic Acid	Tissue repair, neurotransmitter support	
	Serine	Skin hydration, tissue regeneration	

AYURVEDIC PROPERTIES OF *C. asiatica*

C. asiatica has been utilised historically for its memory-boosting properties, which are linked to Alzheimer's disease (AD). AD is a neurological condition that worsens with time and is typified by inappropriate patient conduct and cognitive impairment. Particularly in affluent nations where the number of aged people is growing, it has become one of the most expensive and dangerous diseases, and its incidence is predicted to sharply increase over the coming decades. Cholinesterase inhibitors are now the most prescribed therapeutic class for the treatment of AD, even though the pathophysiology of the disease is still not entirely understood. This is due to the presence of "cholinergic" and "amyloid" theories. Conversely, oxidative stress and iron dysregulation are important variables that can make AD worse. Tyrosinase (TYRO), also known as polyphenol oxidase, is a copper-containing enzyme that is involved in the production of melanin. It may play a role in Parkinson's disease (PD) neuromelanin production and cause TYRO-mediated dopamine neurotoxicity in the brain. Thus, PD patients may benefit from TYRO inhibition. Numerous studies have also connected inflammation to the pathogenesis of neurological conditions including AD and PD.[22]

a) Alzheimer's disease

A gradual and irreversible loss of cognitive function, Alzheimer's disease (AD) is linked to amyloid-beta (Aβ) plaques and tau tangles plaques in the brain's hippocampus. It is the most common kind of dementia in middle-aged and older adults, affecting over five million Americans, and by 2030, an added 7.7 million are predicted to be afflicted. The symptoms of some early-onset forms of the illness often appear after the age of sixty and are linked to a specific genetic defect. Even if the precise origin is unknown, it is certain that 10% to 15% of cases are affected by inherited factors.[18] Age-related, progressive, and irreversible, Alzheimer's disease is characterised by a decline in cognitive function, strange behaviour, personality changes, and severe memory loss. Current investigation showed that the extract from *C. asiatica* may have a notable inhibitory effect on ChEs (2-(Cyclohexylamino) ethanesulfonic acid). *C. asiatica* may be able to raise the amount of the neurotransmitter acetylcholine and enhance synaptic transmission in the AD brain by blocking the enzymes AChEs and BChEs (Acetylcholinesterase and Butyrylcholinesterase) By scavenging reactive free radicals and ROS, which are otherwise crucial in the development of neurofibrillary tangles and neurotic plaques, the plant extract's antioxidant activity also suggested that it had a neuroprotective effect in AD. *C. asiatica* may be an excellent anti-AD agent by working via all these pathways. Thus, more research should be done to identify the chemical compounds that are causing the problem as well as the specific and comprehensive underlying mechanism of action of these chemicals.[23]

Figure 1: Functional properties of *C. asiatica.*

b) Wound Healing

Asiaticoside (AS), the major triterpenoid compound of *C. asiatica*, is often used in traditional medicine to treat wounds and skin-related conditions, such as whitening, keloids, wound healing, and age prevention.[24] Inflammation, cell proliferation, and remodelling are the three overlapping processes that make up wound healing, the most extensively researched function of AS.[9] Skin injuries resulting from trauma, tears, cuts, or contusions are known as skin wounds. The physiological process of wound healing fixes damaged tissues and restores the integrity of the skin. Hemostasias, inflammation, proliferation, and remodelling are the four stages of skin wound healing.[14] In a rabbit incision model, asiaticoside-rich hydrogel derived from the aerial portions of *C. asiatica* promoted skin wound healing more quickly than both the commercial cream and the untreated wounds.[15] The development of a thick layer of

epithelium, keratin, granulation tissues, fibroblasts, and collagen may be the cause of the faster wound healing that occurs when *C. asiatica* hydrogel is applied. Collagen deposition and a high capillary count were seen in the wound areas of rat skin treated with gelatin membranes having *C. asiatica* methanol extract, which resulted in improved skin wound healing.[16]

c) Antioxidant Activity

The potential use of essential oils and other plant extracts as natural supplements has sparked a rising movement to replace synthetic antioxidants with natural ones, which has piqued attention among academics and the food industry. It is commonly recognised that *C. asiatica* has strong antioxidant properties. *C. asiatica* antioxidant activity is on level with that of sage and rosemary, and it has a great deal of promise for use as a natural antioxidant source.[25,26,27] Trolox equivalent antioxidant capacity (TEAC), which is a measure of *C. asiatica* antioxidant qualities, was investigated using the DPPH and FRAP assays.[28] The TEAC values showed a good association, suggesting that the extracts' components may be able to scavenge the DPPH free radical and reduce ferric ions. Using boiling aqueous extraction instead of aqueous extract, *C. asiatica* leaves shown greater antioxidant activity. When compared to aqueous extraction, boiling aqueous extraction also yields higher results for total flavonoid and total phenolic content.[29]

d) Antifungal Activity

Antifungal activity Ethanolic and petroleum ether extracts of *C. asiatica* plant shows significantly higher rate of antifungal activity against various fungal strains like *Aspergillus niger, Aspergillus flavus and Candida albicans* when compared to water extracts.[30] Hexane, carbon tetrachloride, chloroform and aqueous soluble fractions of methanolic extract showed antimicrobial activity against various yeast and Mold strains like *Aspergillus niger, Saccharomyces cerevisiae and Candida albicans* Methanolic extract of *C. asiatica* showed significant inhibitory effect on spore germination against various fungal strains like *Alternaria, Cercospora, Curvularia, Drechslera and Fusarium*.[31] The inhibitory effect on spore germination of the above fungus strains was increased proportionately with the increase in the concentration of methanolic extracts of the leaves.[32,33]

e) Antidiabetic Activity

The ethanolic and methanolic extracts of *C. asiatica* demonstrated notable protection and restored normal blood glucose levels in the alloxan-induced diabetic rats used in the glucose tolerance test. Male Spraque-Dawley rats with diabetes were given plant extract to heal their wounds. When compared to the control group, they discovered that the plant extract-treated lesions epithelialized more quickly.[34] *Centella* extract reduced rats' acute radiation reactivity, which had anti-inflammatory properties. The anti-inflammatory properties of *C. asiatica* water extract and its active ingredient Asiaticoside are caused by the reduction of NO production, which promotes ulcer healing. Crude extract of *C. asiatica* showed anti-inflammatory activity in rats by prostaglandin E2-induced paw edema. Bioactive terpene acids such as asiatic acid and madecassic acid may be present in the crude extract that may account for the anti-inflammatory activities.[35]

f) Memory Enhancing Activity

An aqueous extract of *C. asiatica* reduced the brain's levels of norepinephrine, dopamine, 5-HT, and their metabolites while also improving learning and memory. The plant's aqueous extract proved antioxidant and cognitive-enhancing qualities in rats with oxidative stress and cognitive impairment brought on by streptozotocin. *C. asiatica* aqueous extract treatment during the postnatal developing stage affected the shape of neurones and encouraged the development of higher brain function in juvenile and early adult mice.[36]

g) Cardioprotective Activity

Myocardial necrosis or myocardial infarction (MI) leads to the leakage of cardiac-specific CK and isoenzymes LDH1 and LDH2 from the heart into the blood. Treatment with *C. asiatica* stops the rise in blood marker enzymes that show the plant's cardioprotective properties.[37] The histological results of isoproterenol (ISO)-induced MI of the heart prove necrosis, which is consistent with earlier ISO research. The antioxidant impact of *C. asiatica* (200 mg/kg) reduced necrosis; nevertheless, more molecular level validation is needed. According to research, all these *C. asiatica* medications produced favourable outcomes when taken before to the onset of MI. All experimental models have significant variations from the setting of myocardial infarction in people, even if the current study was created to mimic the real clinical settings of acute myocardial infarction.[38]

h) Skin protective Activity

Studies have shown that 50% ethanol is the best solvent to use in the *C. asiatica* extraction procedure because of the extracts have antioxidant activity and there is less solvent residue, which makes it safe. Callus culture 50% ethanolic extracts have distinct chemical profiles and biological activity. Oxidative stress in dermal fibroblasts is linked to the ageing process of the skin. Therefore, a substance that may stop oxidative damage in dermal fibroblasts may be a good choice for a cosmeceutical product that fights skin ageing. Extracts from *C. asiatica* may increase fibroblasts' ability to get rid of dangerous ROS, which would stop oxidative damage and stop cell death. Gain a better understanding of the protective mechanisms of these extracts on fibroblasts, more research is needed on the protein levels and enzymatic activity of antioxidant machinery.[39]

Future prospective of *C. asiatica* in research and development (Table 3)

i) Development of Neuroprotective Drugs

C. asiatica has attracted lot of interest in the field of neuroscience because of its potential for cognitive improvement and neuroprotection. improved cognition and neuroprotection. The main characteristics of neurodegenerative diseases like Parkinson's disease (PD) and Alzheimer's disease (AD) are neuronal inflammation and oxidative stress. Because of its ability to treat neurotransmitter abnormalities, *C. asiatica* has attracted lot of research in the field of neuroscience. Inhibiting acetylcholinesterase (AChE) and butyrylcholinesterase (BChE), two enzymes that contribute to cholinergic deficits in AD, is one of the ways that the triterpenoids found in *C. asiatica* [asiaticoside, asiatic acid, and madecassoside] have shown neuroprotective effects.[40] These substances also scavenge reactive oxygen species (ROS), reducing the harm that oxidative stress causes to neurones.[41]

ii) Use in Regenerative Medicine

Through cellular regeneration, regenerative medicine looks to repair damaged tissues, and *C. asiatica* shows promise in wound healing and tissue restoration. Tissue regeneration is accelerated by madecassoside and Asiaticoside, which promote collagen production and fibroblast proliferation.[42] Although this feature has well investigated in relation to skin damage, new research shows that it may also have uses in nerve regeneration. By increasing Schwann cell activity and encouraging axonal outgrowth, *C. asiatica* extracts have shown in animal models to aid in peripheral nerve regeneration.[43] These results point to possible therapeutic uses for peripheral neuropathies and spinal cord injuries. *C. asiatica* application in regenerative treatments further supported by its ability to control inflammatory pathways, especially for disorders that call for improved tissue remodelling and wound healing.

iii) Role in Cardiovascular Therapies

Effective cardioprotective drugs must developed since cardiovascular diseases (CVDs) continue to be a major source of morbidity and death globally. By enhancing endothelial function, lowering oxidative stress, and changing lipid metabolism, *C. asiatica* has demonstrated cardioprotective benefits[44]. The plant's flavonoids and saponins lower cholesterol and increase vascular flexibility, both of which may help prevent atherosclerosis. Furthermore, studies show that by reducing oxidative damage in cardiac tissues, *C. asiatica* extracts might lessen ischemia-reperfusion injury.[45] Madecassic acid and asiatic acid's anti-inflammatory qualities also aid in cardioprotection by preventing endothelial dysfunction brought on by cytokines. According to these results, *C. asiatica* may be used in supplemental cardiovascular treatments, especially for those who are susceptible to atherosclerosis and hypertension.

iv) Potential as an Adjunct Cancer Therapy

Because of their potential to improve traditional treatments and lessen side effects, natural substances are being investigated more as adjunct medicines in cancer. Asiatic acid, one of the bioactive substances with anticancer qualities found in *C. asiatica*, has been shown to have cytotoxic effects on a variety of cancer cell lines.[46] It works by inducing apoptosis, stopping the cell cycle, and preventing angiogenesis. Additionally, *C. asiatica* shows promise in reducing oxidative stress and inflammation, two adverse consequences of chemotherapy.[47] Its polyphenolic components' anti-inflammatory and antioxidant qualities may shield non-cancerous cells from harm while undergoing chemotherapy. More thorough investigation is necessary to identify the best doses, administration methods, and potential interactions with traditional anticancer medications, even if early trials indicate that it is effective in treating cancer.

v) Pharmacological Advancements and Biotechnology

Biotechnology developments have significantly expanded *C. asiatica* pharmaceutical potential. Drug delivery methods based on nanotechnology have been investigated to increase the active ingredients' bioavailability and therapeutic effectiveness. For example, asiaticoside and madecassoside nanoencapsulation has demonstrated enhanced stability and targeted distribution, augmenting their pharmacological effects.[48] These methods could offer more effective treatment results for cardiovascular disorders, wound healing, and neurodegenerative illnesses. Additionally, genetic engineering and tissue culture methods have been used to maximise *C. asiatica* synthesis of bioactive chemicals. The output of secondary metabolites of pharmacological significance has been enhanced by biotechnological interventions, such as elicitor-mediated in vitro cultures.[49] These techniques have the potential to produce chemicals derived from *C. asiatica* on a big scale and sustainably for medical use.

Table 3: Future research prospects of *Centella asiatica* in biomedical applications.

Research Area	Focus	Potential Applications	Key Bioactive Compounds / Mechanism
Neuroprotection	Cognitive enhancement, neurodegeneration prevention	Alzheimer's disease (AD), Parkinson's disease (PD), memory loss	Inhibition of AChE and BChE; antioxidative action of siaticoside, asiatic acid
Regenerative Medicine	Tissue repair and wound healing	Skin regeneration, peripheral nerve regeneration	Madecassoside and asiaticoside promote collagen synthesis and

			fibroblast proliferation
Cardiovascular Therapies	Protection against ischemic injury, lipid regulation	Myocardial infarction, hypertension, atherosclerosis	Antioxidant and anti-inflammatory effects; improved endothelial function
Adjunct Cancer Therapy	Cytotoxicity toward cancer cells, support during chemotherapy	Complementary cancer treatment	Asiatic acid induces apoptosis, inhibits angiogenesis, reduces chemo-induced toxicity
Biotechnology & Pharmacology	Enhancing therapeutic delivery and bioavailability	Improved drug delivery systems, sustained release formulations	Nanoencapsulation of asiaticoside and madecassoside
Sustainable Production	Large-scale synthesis of active compounds via plant biotechnology	Consistent production for pharmaceuticals and cosmeceuticals	Callus culture, elicitor-mediated in vitro techniques

CONCLUSION

Centella asiatica is an important plant in Ayurvedic medicine that has long been known for its neuroprotective and memory-boosting properties. The demand for this plant in the pharmaceutical and cosmeceutical sectors has surpassed the supply from traditional farming because of its great medicinal potential. Recent studies have demonstrated that its anti-inflammatory and antioxidant properties can help manage neurological diseases like Parkinson's and Alzheimer's and enhance cognition. In addition to providing cognitive support, *C. asiatica* promotes collagen production and tissue regeneration, which aids in wound healing and skin protection. Its antifungal, antidiabetic, and cardioprotective qualities highlight its therapeutic adaptability even more. A production method provided by callus culture guarantees a steady supply of chemicals with consistent quality and high yields. In addition, recent developments in biotechnology, such as tissue culture and nanoencapsulation, further improve the yield and effectiveness of its bioactive substances. To standardise its application and fully realise its advantages in contemporary medicine, more research is necessary.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest regarding this paper.

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