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CENTELLA ASIATICA IN THE MODERN THERAPEUTIC LANDSCAPE

Miss. Tapkir Puja Sunil, Prof. Katore S.R., Dr. Bhosale M.P.
Dharmraj Shaikshanik Pratishthan College of Pharmacy, Walki, Ahilyanagar

**Corresponding Author: Tapkir Puja Sunil, Dharmraj Shaikshanik Pratishthan College of Pharmacy, Walki, Ahilyanagar, Maharashtra, India, 414006.*

ABSTRACT

A traditional medicinal plant in Ayurveda and Traditional Chinese Medicine, Centella asiatica, often known as Gotu kola, has made a comeback as a significant phytotherapeutic agent in contemporary pharmacology. Numerous biological activities, such as neuroprotective, wound-healing, antioxidant, anti-inflammatory, antidiabetic, and cardioprotective properties, are supported by its rich composition of triterpenoids, especially asiaticoside, madecassoside, and Asiatic acid. Its capacity to alter several molecular pathways, including NF-κB, COX-2, and MAPK, has been demonstrated in recent studies to support tissue regeneration and cellular defence. C. asiatica has been successfully added to innovative drug delivery systems like liposomes, Nano emulsions, phytosomes, and hydrogels to improve bioavailability and targeted efficacy thanks to developments in nanotechnology and formulation science. Furthermore, both in vitro and clinical studies are being conducted to investigate its potential use in metabolic syndromes, neurological diseases, and dermatology. Despite encouraging results, issues with large-scale clinical validation, standardisation, and dosage optimization still exist. With a focus on its phytochemical variety, pharmacological mechanisms, novel formulations, clinical potential, and future prospects in evidence-based Phytomedicine, this study critically analyses Centella asiatica's changing significance in the contemporary therapeutic environment.

KEYWORDS: *Centella asiatica; Gotu kola; Asiaticoside; Madecassoside; Phytomedicine; Neuroprotection; Wound healing; Nanotechnology; Herbal therapeutics; Modern pharmacology; Triterpenoids.*

INTRODUCTION

Herbal remedies have gained popularity all over the world in recent decades as possible therapeutic substitutes for synthetic drugs. *Centella asiatica* (L.) Urban, sometimes referred to as Indian pennywort or Gotu kola, is one of the many medicinal plants that has drawn a lot of scientific and medical interest because of its advantageous safety profile and wide range of pharmacological effects. *C. asiatica* has evolved from traditional folklore into evidence-based contemporary Phytotherapy, after being traditionally regarded in Ayurvedic, Chinese, and Indonesian medical systems for fostering longevity, improving memory, and mending wounds. It is a viable option for contemporary medication development and integrative medicine due to its exceptional versatility in a variety of pharmacological scenarios[1-2].

The perennial creeping plant *Centella asiatica* is a member of the Apiaceae (Umbelliferae) family. The plant, which is known for its distinctive fan-shaped leaves and tiny white to pinkish blooms, grows well in tropical and subtropical areas of Asia, such as China, Indonesia, India, and Sri Lanka. The rich phytochemical content of *C. asiatica,* especially the triterpenoid saponins (asiaticoside, madecassoside, Asiatic acid, and madecassic acid), flavonoids, tannins, alkaloids, phytosterols, and volatile oils, is thought to be responsible for its medicinal potential. The herb's pharmacological qualities, including as neuroprotection, wound healing, anti-inflammatory, antioxidant, antidiabetic, hepatoprotective, and anti-anxiety effects, are all influenced by these bioactive chemicals used together[3-4].

Centella asiatica has become well-known as a natural neurotherapeutic and dermatological agent in the current therapeutic environment. Because of its capacity to promote neurite outgrowth, lower oxidative stress, and alter neurotransmitter levels, it has been shown in several studies to hold promise in the treatment of neurodegenerative illnesses including Parkinson's and Alzheimer's. With evidence of increased collagen synthesis, angiogenesis, and re-epithelialization, its application in dermatology and wound healing has also grown. As a result, C. asiatica extracts are now essential components of several dermatological and cosmeceutical compositions meant to increase skin suppleness, lessen scarring, and postpone ageing[5-6].

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The molecular mechanisms of action of the herb are closely related to its pharmacological activities. According to studies, *C. asiatica* and its triterpenoids have a major impact on cellular signalling pathways such PI3K/Akt, COX-2, MAPK, and NF-κB, which in turn affects tissue regeneration, inflammation, and oxidative balance. Furthermore, it is known that asiaticoside and madecassoside promote collagen type I production and fibroblast proliferation, both of which are critical for tissue regeneration and repair. Its therapeutic value in both acute and chronic disorders involving oxidative and inflammatory stress is highlighted by its mechanistic plasticity[7-8].

Despite its potential for therapeutic use, *Centella asiatica's* quick metabolism, limited bioavailability, and poor water solubility greatly limit the systemic absorption of its active ingredients in pharmaceutical applications. Modern formulation technologies, such as solid lipid nanoparticles, liposomes, phytosomes, Nano emulsions, and polymeric hydrogels, are being investigated to get around these obstacles. The pharmacodynamic potential of *C. asiatica* drugs is maximised by these innovative drug delivery methods, which improve solubility, stability, and targeted administration. The medicinal potential of this ancient plant is being redefined by the fusion of contemporary nanotechnological innovation and traditional herbal expertise[9-10].

Additionally, the adaptogenic and nootropic qualities of *C. asiatica* are being studied, especially in relation to enhancing cognitive function, lowering stress levels, and alleviating anxiety disorders. According to recent clinical research, those who take standardised *C. asiatica* extract supplements report advantages in mood control, mental clarity, and memory recall. Its incorporation into modern treatment plans for mental health and neuroprotection is supported by this research[11-12].

Apart from its neurological and dermatological uses, *Centella asiatica* also has anti-diabetic, cardioprotective, and anti-cancer qualities. These are mediated via normalising lipid profiles, inhibiting the growth of tumour cells, and modifying glucose metabolism. In contemporary clinical research, *C. asiatica* is positioned as a multi-target phytotherapeutic agent due to its wide therapeutic range[13].

Phytochemistry

Triterpenoid saponins, namely asiaticoside, madecassoside, and their aglycone, Asiatic acid and madecassic acid, are abundant in *Centella asiatica* and are in charge of the majority of its pharmacological effects. Flavonoids, tannins, polyphenols, sterols, volatile oils, and amino acids are also present in the plant. These substances support its neuroprotective, anti-inflammatory, and antioxidant properties. Techniques such as LC-MS and high-performance liquid chromatography (HPLC) have verified their existence in standardised extracts. Their concentration is influenced by seasonal and environmental factors, so meticulous quality control is required. The wide range of therapeutic benefits of *C. asiatica* is supported by the synergistic action of various phytoconstituents, which also facilitates their incorporation into contemporary phytopharmaceuticals formulations[14-15].



Fig.1: Leaves of *Centella asiatica*

Pharmacological Activities

Centella asiatica has a wide range of pharmacological characteristics, such as anti-inflammatory, neuroprotective, hepatoprotective, wound-healing, antidiabetic, and anti-anxiety effects. Asiaticoside and madecassoside promote tissue regeneration by inducing collagen production, angiogenesis, and fibroblast proliferation. Neurotransmitter regulation and oxidative stress reduction are the sources of the plant's neuroprotective benefits. It protects hepatic organs while lowering blood glucose and cholesterol levels in metabolic diseases. It

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has anti-aging and skin healing properties because of its antioxidant activity, which fights reactive oxygen species. These diverse actions support *C. asiatica's* status as a flexible medicinal substance with the ability to prevent and treat a variety of disease conditions[16-17].

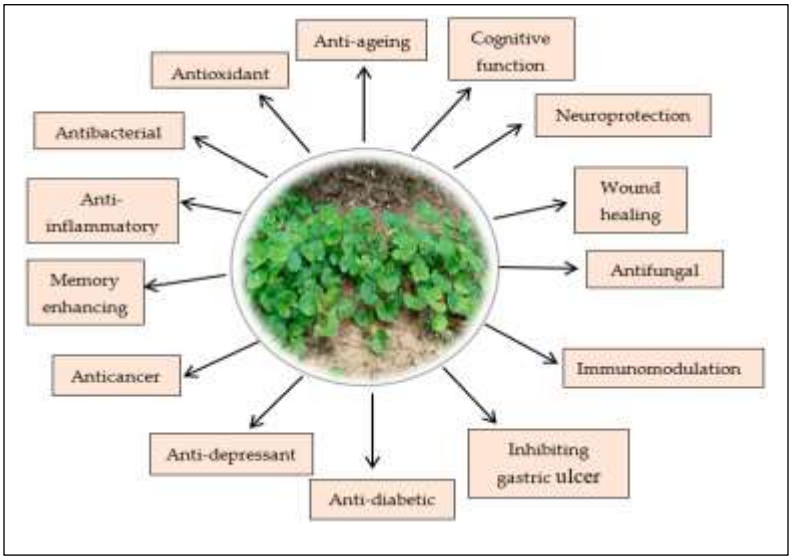


Fig.2: Pharmacological activities of *C. asiatica's*

Mechanisms of Action

Centella asiatica has a wide range of pharmacological characteristics, such as anti-inflammatory, neuroprotective, hepatoprotective, wound-healing, antidiabetic, and anti-anxiety effects. Asiaticoside and madecassoside promote tissue regeneration by inducing collagen production, angiogenesis, and fibroblast proliferation. Neurotransmitter regulation and oxidative stress reduction are the sources of the plant's neuroprotective benefits. It protects hepatic organs while lowering blood glucose and cholesterol levels in metabolic diseases. It has anti-aging and skin healing properties because of its antioxidant activity, which fights reactive oxygen species. These diverse actions support *C. asiatica's* status as a flexible medicinal substance with the ability to prevent and treat a variety of disease conditions[18-19].

Advantages

- *Centella asiatica*, commonly known as Gotu Kola, holds a prominent place in the modern therapeutic landscape due to its wide range of pharmacological benefits.
- It exhibits potent antioxidant, anti-inflammatory, wound-healing, neuroprotective, and anti-anxiety properties[20-21].
- The bioactive compounds, mainly asiaticoside, madecassoside, and Asiatic acid, contribute to collagen synthesis and skin regeneration, making it valuable in dermatology and cosmetic formulations[22-23].
- Additionally, Centella asiatica enhances cognitive function, memory, and mental clarity, supporting neurological health[24-25].
- Its adaptogenic and circulatory benefits aid in managing stress, venous insufficiency, and diabetic complications. Overall, it bridges traditional medicine with evidence-based modern therapeutics[26-27].

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Available Marketed Formulations

Table.1: Available Marketed formulations

Sr. No.	Product Name	Type / Form	Image Reference Name
1	SKIN1004 Madagascar Centella Spot Cream	Spot cream	
2	Tatha Firming Cream With Peptides & Centella Asiatic Plant Stem Cells	Firming / anti-aging cream	
3	ONE THING Centella Asiatica Extract 95%	Extract / toner-type / base	
4	Mystiqare Centella Asiatica (CICA) Overnight Repair Gel	Gel-cream moisturizer	
5	KOA Herbs Night Restore Cream	Night cream	
6	Serene oil free moisturiser Face Cream	Face cream (for sensitive skin)	

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Novel Formulations and Drug Delivery Systems

- Researchers have created sophisticated drug delivery methods, including hydrogels, liposomes, phytosomes, Nano emulsions, and polymeric nanoparticles, to get around *Centella asiatica's* low water solubility and restricted bioavailability[28].
- These technologies improve the target-specific distribution, regulated release, and permeability of active substances such as madecassoside and asiaticoside. While topical hydrogels and nanogels offer continuous skin administration for wound healing and anti-aging benefits, phytosomal formulations enhance oral absorption[29].
- For improved skin regeneration, recent research also investigates transdermal patches and nanofibers filled with *C. asiatica*. These developments bridge the gap between cutting-edge pharmaceutical technology and traditional herbal uses, greatly improving therapeutic effects[30-32].

Clinical Studies and Therapeutic Efficacy

- *Centella asiatica* has shown encouraging therapeutic results in clinical studies for a variety of illnesses.
- Oral extracts enhance cognitive function and lessen anxiety symptoms, while topical preparations hasten wound healing and minimise scarring. Patients with chronic venous insufficiency have shown improved venous tone and microcirculation in controlled studies.
- Creams with madecassoside are used in dermatology to increase the moisture and suppleness of the skin. Furthermore, *C. asiatica* has neuroprotective advantages in diabetic neuropathy and moderate cognitive impairment.
- Larger, standardised clinical trials are required to determine the precise dose, formulation, and long-term treatment effects, even though the majority of research confirm its safety and effectiveness[33-35].

Recent Trends and Innovations:

- Integrating *Centella asiatica* into functional foods, cosmeceuticals, and nanomedicine is a recent trend. Green synthesis developments have made it possible to create environmentally friendly nanoparticles with increased bioactivity by employing *C. asiatica* extracts.
- Triterpenoids' biosynthesis routes are being uncovered by genomic and metabolomic research in order to produce them biotechnologically.
- Targeted delivery and tissue regeneration have been enhanced by novel formulations such 3D biopolymer scaffolds, Nano-hydrogels, and microneedle patches.
- The herb is being used in cosmetics to make skin repair and anti-aging serums. These developments signal a move in the current therapeutic and economic environments towards technology-driven, evidence-based uses of *C. asiatica*[36-37].

Challenges

- Despite its potential for medicinal use, *Centella asiatica* has issues with stability, standardisation, and clinical validation. Batch-to-batch uniformity is hampered by seasonal and regional variations in phytochemical composition.
- Systemic effectiveness is limited by fast metabolism and limited oral absorption. Dose optimization is made more difficult by inadequate pharmacokinetic data and a lack of well identified biomarkers. Moreover, regulatory approval is restricted by differences in extraction techniques and a dearth of extensive, randomized clinical studies.
- Obstacles also arise from conventional knowledge's intellectual property concerns. For *C. asiatica* to be accepted as a pharmaceutical worldwide, these issues must be resolved by sophisticated analytical methods, formulations based on nanotechnology, and reliable clinical testing[38-40].

CONCLUSION

One outstanding illustration of how conventional herbal medicine and contemporary science may coexist to produce therapeutically useful treatments is Centella asiatica. Its bioactive triterpenoids, Asiatic acid, madecassoside, and asiaticoside, have a variety of pharmacological activities, such as anti-inflammatory, neuroprotective, wound-healing, and antioxidant properties. Developments in formulation technologies, including hydrogels, liposomes, and nanoparticles, have greatly increased its therapeutic potential and bioavailability. Clinical research supports its effectiveness and safety in treating vascular, neurological, and dermatological conditions. But there are still issues with large-scale clinical validation, dose optimization, and standardisation. The creation of internationally standardised formulations, sustainable cultivation, and the clarification of molecular mechanisms should be the main areas of future study. Centella asiatica continues to develop as a promising natural agent in the contemporary therapeutic environment by fusing cutting-edge pharmaceutical technology with traditional knowledge, providing enormous potential for evidence-based Phytomedicine and customised healthcare applications.

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