Ethnobotany and Scientific Evidence of Centella asiatica: From Traditional Medicine to Functional Foods

Melissa Soun-Udom, and Sutsawat Duangsrisai
Department of Botany, Faculty of Science, Kasetsart University
Email: fscissw@ku.ac.th

Received August 24, 2025; Revised December 30, 2025; Accepted December 31, 2025

Abstract

Centella asiatica (Gotu Kola) is a medicinal herb of significant importance in both traditional medicine and modern medical applications. Its bioactive compounds, such as asiaticoside and madecassoside, possess a wide range of pharmacological properties, including wound healing, anti-inflammatory effects, neuroprotection, and cognitive enhancement. These attributes have solidified the plant's role as a key component in contemporary functional foods and biomedical products. Ethnobotanical studies have highlighted the cultural and medicinal significance of *C. asiatica* across various Asian societies, while modern scientific research has validated and expanded its traditional uses. Optimizing cultivation processes, particularly in regions with favorable climatic conditions such as Thailand, is critical to meet the growing global demand for high-quality *C. asiatica*. Despite the challenges posed by the variability of bioactive compound concentrations, these issues present an opportunity for further research to refine cultivation techniques, ensuring consistency in the bioactivity and efficacy of the plant. Continued exploration and research will not only enhance confidence in its therapeutic properties but also support its integration into both traditional and modern medical practices, while ensuring sustainable cultivation practices for the future. The integration of C. asiatica into functional foods and nutraceuticals faces certain challenges, notably the variability in concentrations of bioactive compounds. However, these challenges present opportunities for further research to standardize cultivation techniques and ensure consistency in product potency and efficacy. Future studies, particularly large-scale randomized controlled trials, are essential to substantiate the long-term health benefits of this herb and solidify its role in both traditional and modern medical practices. Ongoing research not only enhances our comprehension of the plant's full potential but also opens avenues for discovering novel therapeutic applications and refining cultivation methodologies, ensuring its sustainable use in the future.

Keywords: Ethnobotany, Scientific Evidence, *Centella asiatica*, Secondary metabolites, Bioactive Properties

Introduction

Centella asiatica, commonly referred to as Gotu Kola, is a renowned medicinal herb that has been esteemed in Asia for centuries. Its utilization spans a myriad of therapeutic applications, owing to its diverse pharmacological properties. (Arora et al., 2018) The plant harbors bioactive compounds that are instrumental in neuroprotection, anti-inflammatory responses, enhancement of circulatory dynamics, and facilitation of wound healing. Furthermore, it is prized in dermatological treatments for its restorative effects on the skin. In

contemporary contexts, *C. asiatica* has gained significant global traction, finding its way into nutraceuticals and cosmeceuticals, underscoring its substantial relevance both locally and internationally. (Brinkhaus et al., 2000)

From an ethnobotanical perspective, the study of *C. asiatica* involves an exploration of indigenous knowledge passed down through generations. Local communities have long harnessed the plant's healing potential for a wide array of health conditions. Modern scientific inquiry has corroborated these traditional uses, unveiling the molecular mechanisms underlying its therapeutic actions. (Das, 2011) For instance, the identification of triterpenoid compounds such as asiaticoside, which stimulate cellular regeneration and wound repair, exemplifies how empirical research can substantiate the therapeutic claims rooted in traditional practices. As such, scientific research serves to augment and validate ethnobotanical knowledge, facilitating the convergence of indigenous wisdom and contemporary pharmacology. (Arora et al., 2018)

Beyond its medicinal value, *C. asiatica* holds substantial socio-economic significance. In numerous Asian regions, it serves as a vital economic resource, with local communities cultivating and commercializing the herb in both its raw and processed forms. (Jan et al., 2021) Products derived from Centella, such as medicinal preparations, cosmetic formulations, and dietary supplements, contribute to local economies, fostering job creation and promoting sustainable agricultural practices. The cultivation of Centella is particularly noteworthy and its adaptability to diverse ecological environments, further enhancing its role in promoting sustainable development. (Vasanth et al., 2021)

However, there remain notable gaps in the research concerning the ethnobotanical and scientific dimensions of *C. asiatica*, particularly regarding the translation of traditional knowledge into scientifically validated health benefits. Despite its extensive historical use, the scientific understanding of the plant's pharmacodynamics and underlying biochemical pathways remains underdeveloped in certain areas. (Brinkhaus, 2000) One critical gap lies in the integration of ethnobotanical data with molecular pharmacology to elucidate the plant's effects at the cellular and molecular levels. Furthermore, while Centella is widely used in functional foods and cosmetics, comprehensive studies on its long-term safety profile and potential adverse effects, especially at higher dosages, are still lacking. (Hossain et al., 2021)

Therefore, an interdisciplinary approach that bridges ethnobotanical insight with rigorous scientific inquiry is paramount for the advancement of our understanding of *C. asiatica*. Such research would not only validate its efficacy in traditional medicine but also pave the way for the development of novel, scientifically substantiated therapeutic agents and functional foods that can be safely utilized in clinical and consumer contexts.

Ethnobotany and Traditional Uses of Centella asiatica

Ethnobotany is a field that bridges cultural practices and botanical science by studying the traditional knowledge of indigenous communities regarding the use of plants in various aspects such as medicine, nutrition, and cultural practices. (Changsan, 2023) In the case of *Centella asiatica*, commonly known as Gotu Kola, ethnobotanical studies help us understand the significance of this herb as a vital medicinal plant in many Asian countries, particularly in India, Sri Lanka, China, and Thailand, where *C. asiatica* has been widely used in traditional medicine systems for centuries. (Sun et al., 2020)

Historically, *C. asiatica* has been revered as a medicinal herb with a wide range of therapeutic properties, including its use to treat conditions such as skin diseases, cognitive enhancement, wound healing, and overall health promotion. In Ayurvedic medicine, *C. asiatica* is known as "Brahmi," reflecting its association with promoting mental clarity and enhancing brain function. It is also used to treat anxiety, stress, and depression, as well as to improve memory and concentration. Similarly, in Traditional Chinese Medicine (TCM), *C. asiatica* is believed to stimulate blood circulation, alleviate pain, and support the healing of ulcers and wounds. (Gohil et al., 2010)

In addition to its medicinal applications, *C. asiatica* holds cultural and symbolic significance in many Asian communities. In certain regions, *C. asiatica* is considered a sacred plant, believed to possess spiritual healing properties, and is often used in religious ceremonies and rituals to purify the body and mind. The herb is associated with rejuvenation and longevity and is consumed in various forms such as herbal teas or soups, which are believed to contribute to a long and healthy life. (Hein et al., 2025)

The widespread use and revered status of *C. asiatica* in Asian societies highlight its enduring role as a plant of considerable importance in medicine, nutrition, and culture. Through the study of ethnobotany, we gain a deeper understanding of the profound connection between indigenous knowledge and plant-based therapies, which continue to influence contemporary pharmacology and alternative medicine. (Ebau et al., 2023) The ongoing exploration and preservation of such traditional plant knowledge not only provide insights into indigenous cultures but also serve as a foundation for discovering new health benefits of plants that have been used for centuries. (Chandrika & Prasad, 2015)

In conclusion, *C. asiatica* (Gotu Kola) is a plant of profound cultural, medicinal, and nutritional importance in many Asian societies. Its extensive use in traditional medicine systems, particularly in Ayurveda and Traditional Chinese Medicine, demonstrates its diverse therapeutic properties, ranging from cognitive enhancement to wound healing and skin care. Beyond its medicinal value, the herb holds significant cultural and spiritual meaning, symbolizing rejuvenation, longevity, and purity. The study of ethnobotany enhances our understanding of the deep connection between indigenous knowledge and plant-based therapies, shedding light on the enduring relevance of traditional medicinal practices. By preserving and further exploring this knowledge, we not only gain valuable insights into the cultural heritage of indigenous communities but also uncover potential new health benefits from plants that have been used for centuries.

Pharmacological and Biological Activities of Centella asiatica

Centella asiatica (Gotu Kola) has garnered significant attention in the fields of pharmacology and biomedicine, owing to its extensive array of bioactive compounds that demonstrate diverse therapeutic properties. (Gohil, 2010) These properties have been extensively explored through various scientific methodologies, including in vitro (laboratory-based), in vivo (animal model-based), and clinical trials, which collectively underscore its profound biological effects on human health. The pharmacological potential of *C. asiatica* is attributed primarily to its rich chemical composition, which includes bioactive compounds such as triterpenoids, flavonoids, and phenolic compounds, all of which contribute to its diverse therapeutic effects. (Sudhakaran, 2017)

The most prominent active compounds in *C. asiatica* are triterpenoids, specifically asiaticoside and madecassoside, which have been shown to exert a wide range of biological activities. (Hossain et al., 2021) Asiaticoside, in particular, is known for its potent wound-healing properties, as it promotes collagen synthesis and fibroblast proliferation, accelerating

the repair of damaged skin tissues. Additionally, these triterpenoids possess anti-inflammatory and antioxidant properties, which contribute to their role in reducing oxidative stress and inflammation, both of which are key factors in the pathogenesis of various chronic diseases, including cardiovascular diseases and neurodegenerative disorders. (Bylka et al., 2014)

Flavonoids found in *C. asiatica*, such as quercetin, kaempferol, and rutin, also contribute to its therapeutic effects, exhibiting strong antioxidant, anti-inflammatory, and anticancer activities. These flavonoids help mitigate the damage caused by free radicals, thereby protecting cells from oxidative stress, which is a significant contributor to aging and the development of various diseases. Furthermore, flavonoids have been shown to improve blood circulation, promote brain health, and enhance cognitive function, making *C. asiatica* a valuable herb for improving mental clarity and treating conditions like anxiety and depression. (Ruszymah et al., 2012)

Additionally, phenolic compounds present in *C. asiatica* such as tannins and gallic acid further enhance its pharmacological profile. These compounds exhibit potent antimicrobial, antiviral, and anti-inflammatory activities, providing significant protective effects against microbial infections and chronic inflammatory conditions. Phenolic compounds also contribute to the herb's ability to modulate immune function, thus promoting overall health and reducing susceptibility to infections. (Torbati et al., 2021)

In terms of its biological activities, *C. asiatica* has been widely investigated for its neuroprotective effects. Studies have demonstrated that the active compounds in *C. asiatica* can protect neurons from oxidative damage, thus potentially reducing the risk of cognitive decline and offering therapeutic benefits for conditions such as Alzheimer's disease and Parkinson's disease. Its ability to enhance cognitive function, memory, and focus further underpins its use as a traditional tonic for brain health. (Prakash et al., 2017)

The adaptogenic properties of *C. asiatica* also make it a valuable herb in combatting stress and fatigue. Through modulation of the hypothalamic-pituitary-adrenal (HPA) axis, *C. asiatica* can regulate the body's stress response, thereby reducing the physiological effects of stress, such as anxiety and high blood pressure. This adaptogenic action contributes to its widespread use in enhancing overall resilience and improving physical endurance. (Nurlaily et al., 2012)

In addition to its neuroprotective and anti-inflammatory properties, *C. asiatica* has shown promise in improving skin health. Its ability to promote collagen synthesis and accelerate wound healing has led to its incorporation in numerous skincare products. Clinical studies have validated its efficacy in reducing the appearance of scars, stretch marks, and wrinkles, making it a popular ingredient in topical formulations aimed at skin rejuvenation. (Witkowska et al., 2023)

In conclusion, *C. asiatica* (Gotu Kola) has emerged as a highly valued medicinal herb due to its extensive pharmacological and therapeutic properties, which are primarily attributed to its rich chemical composition, including triterpenoids, flavonoids, and phenolic compounds. These bioactive compounds contribute to a wide range of beneficial effects, such as wound healing, anti-inflammatory, antioxidant, neuroprotective, and cognitive-enhancing properties. Additionally, *C. asiatica* has shown promise in improving skin health and combating stress, further cementing its significance in both traditional and modern medicine. Through extensive scientific research, including in vitro, in vivo, and clinical trials, the herb's biological effects on human health continue to be validated, highlighting its potential as a natural remedy for various chronic conditions, enhancing mental clarity, resilience, and overall well-being. As research progresses, *C. asiatica* is likely to offer even more therapeutic applications,

solidifying its place as a powerful and versatile plant in the field of pharmacology and biomedicine.

Secondary Metabolites of *Centella asiatica*

Centella asiatica (Gotu Kola) is renowned not only for its broad pharmacological and therapeutic effects but also for the extensive array of secondary metabolites it contains. These bioactive compounds, which are responsible for the plant's medicinal properties, are also key to its natural defense mechanisms against environmental stresses, herbivory, and microbial pathogens. (Li et al., 2016) Secondary metabolites are a class of organic compounds that plants produce to enhance their survival and resilience, providing them with protection against various environmental threats. In the case of *C. asiatica*, these metabolites include triterpenoids, flavonoids, alkaloids, and phenolic compounds, each of which contributes to the plant's therapeutic effects and biological activities. (Ebau et al., 2023)

Triterpenoids are perhaps the most well-studied group of secondary metabolites in *C. asiatica*, with asiaticoside and madecassoside being the most prominent. These triterpenoids are known for their anti-inflammatory, wound-healing, and collagen-promoting properties. Asiaticoside, in particular, has demonstrated a significant ability to stimulate collagen synthesis and promote fibroblast proliferation, making it highly effective in wound healing and skin regeneration. Additionally, triterpenoids in *C. asiatica* exhibit potent antioxidant activity, neutralizing free radicals and reducing oxidative stress, which is a contributing factor in aging and the development of chronic diseases. (Ryall et al. 2022)

Flavonoids, another critical class of secondary metabolites in *C. asiatica*, include compounds such as quercetin, kaempferol, and rutin. Flavonoids are known for their powerful antioxidant, anti-inflammatory, and antimicrobial properties. (Torbati, 2021) These compounds help reduce oxidative damage by scavenging free radicals, thus protecting cells from the damaging effects of environmental stressors such as UV radiation and pollution. Moreover, flavonoids play an essential role in improving circulation, promoting brain health, and enhancing cognitive function. Their anti-inflammatory and neuroprotective properties make *C. asiatica* an effective remedy for conditions such as cognitive decline, anxiety, and depression. (Paocharoen, 2010)

Alkaloids, though present in smaller quantities in *C. asiatica*, contribute to its therapeutic potential, particularly through their effects on the nervous system. Alkaloids have been shown to have neuroprotective effects, influencing neurotransmitter systems and offering potential benefits for the treatment of neurological conditions. These compounds also contribute to the herb's overall adaptogenic properties, helping the body to better respond to stress and environmental challenges. (Kuo et al., 2012)

Phenolic compounds, including tannins, flavonoids, and gallic acid, are significant contributors to *C. asiatica*'s broad spectrum of biological activities. These compounds possess strong antimicrobial, antioxidant, and anti-inflammatory properties. (Yang, 2018) Phenolic compounds help combat oxidative stress and reduce the inflammatory response, which is particularly important in managing chronic diseases such as cardiovascular disease, diabetes, and neurodegenerative disorders. Additionally, the antimicrobial properties of phenolic compounds provide *C. asiatica* with a natural defense against pathogens, contributing to its use in folk medicine for treating infections and promoting general health. (Hossain, et al. (2021).

In terms of its ecological role, the production of these secondary metabolites in *C. asiatica* serves as a crucial defense mechanism. For instance, the triterpenoids, phenolics, and alkaloids produced by the plant not only deter herbivores but also serve to protect the plant from pathogens and environmental stresses, such as extreme temperatures, drought, and UV

radiation. This biochemical arsenal enables *C. asiatica* to thrive in diverse environmental conditions and reinforces its adaptability as a medicinal plant. (Paocharoen, 2010)

The rich diversity of secondary metabolites in *C. asiatica* makes it a versatile plant with a wide range of pharmacological and therapeutic applications. These compounds are central to the plant's effectiveness in treating various health conditions, ranging from wound healing and skin regeneration to cognitive enhancement, anti-inflammatory therapy, and stress adaptation. As research into the bioactive compounds of *C. asiatica* continues, it is likely that new therapeutic uses for this plant will emerge, further solidifying its value as a key natural remedy in both traditional and modern medicine. The ongoing exploration of its secondary metabolites also highlights the complex relationship between a plant's chemical composition and its ecological interactions, underscoring the importance of preserving and studying such medicinal plants for future generations. (Torbati et al., 2021)

In conclusion, *C. asiatica* (Gotu Kola) stands out as a highly valuable medicinal plant, largely due to its diverse array of secondary metabolites, including triterpenoids, flavonoids, alkaloids, and phenolic compounds. These bioactive compounds not only contribute to the plant's therapeutic properties such as wound healing, anti-inflammatory, antioxidant, and neuroprotective effects but also play a crucial role in its defense mechanisms against environmental stresses, herbivory, and pathogens. The production of these metabolites enhances the plant's resilience and adaptability in diverse environmental conditions, further cementing its status as a versatile and potent medicinal herb. The pharmacological potential of *C. asiatica* is reflected in its ability to treat a variety of health conditions, ranging from skin regeneration and cognitive enhancement to stress adaptation and chronic disease management. As research into its bioactive compounds continues, new therapeutic applications are likely to emerge, solidifying *C. asiatica*'s place in both traditional and modern medicine. The continued study of its secondary metabolites highlights the intricate relationship between plant chemistry and ecological interactions, underscoring the importance of preserving and understanding such plants for future medical and ecological applications.

Environmental and Cultivation Influences on Centella asiatica

The growth, chemical composition, and therapeutic properties of *Centella asiatica* (Gotu Kola) are highly influenced by environmental factors and cultivation practices. Understanding these influences is critical for optimizing its cultivation for both traditional medicinal uses and modern commercial applications. Environmental conditions, soil quality, climate, and cultivation techniques all contribute to the plant's growth, yield, and secondary metabolite production, which directly impacts its pharmacological effectiveness.

1) Environmental Factors Influencing Growth and Chemical Synthesis

Light intensity and photoperiod are critical factors in enhancing the production of bioactive compounds in *C. asiatica*. Studies have shown that growing the plant under high-intensity light conditions, such as LED light with a photosynthetic photon flux density (PPFD) of 330 µmol/m²/s, leads to maximum production of triterpene glycosides and antioxidant activity, compared to natural or fluorescent lighting. Furthermore, the application of specific nutrient solutions plays a pivotal role in enhancing the biosynthesis of bioactive compounds such as asiaticoside and madecassoside, which possess anti-inflammatory properties and promote wound healing. The use of organic fertilizers and balanced nutrient solutions has been found to increase both the yield and the pharmacological quality of the plant. (Yang et al., 2018; Sudhakaran, 2017)

2) Impacts of Temperature and CO_2 Concentration on Secondary Metabolite Synthesis

Climate change, particularly the rise in atmospheric CO_2 concentration and temperature, has profound effects on secondary metabolite synthesis in plants. *C. asiatica* has been shown to exhibit altered chemical profiles under elevated CO_2 conditions, resulting in variations in pharmacologically active compounds. Such environmental stressors can lead to enhanced production of secondary metabolites as a plant adaptive mechanism, which may influence the overall medicinal efficacy of the plant. (Jan et al., 2021; Prakash, 2017)

3) Cultivation in Thailand

Thailand, with its humid climate and fertile soil, provides an optimal environment for cultivating *C. asiatica*, particularly in wetlands or riparian zones. Managing environmental factors, such as the appropriate use of organic fertilizers and light control, has been shown to significantly enhance both yield and the pharmacological quality of the plant. Field studies in various regions of Thailand have confirmed the potential for large-scale cultivation of this plant for commercial and medicinal use. (Changsan et al., 2023)

4) Pharmacological Properties

The bioactive compounds in *C. asiatica*, such as asiaticoside, madecassoside, asiatic acid, and madecassic acid, are widely recognized for their potent pharmacological activities. These compounds possess anti-inflammatory, antioxidant, and wound-healing properties, making them valuable for treating dermatological conditions and promoting tissue regeneration. Additionally, the compounds stimulate collagen synthesis, a critical process for wound healing and skin regeneration. They also play a significant role in neuroprotection, with studies showing that *C. asiatica* may help reduce amyloid beta levels and inhibit BACE1, thus potentially aiding in the treatment of Alzheimer's disease. (Shen et al., 2019; Paocharoen, 2010)

In conclusion, the cultivation of *C. asiatica* (Gotu Kola) is profoundly influenced by a variety of environmental factors such as light intensity, temperature, CO_2 concentration, soil quality, and nutrient management. These factors not only affect the plant's growth and yield but also play a crucial role in enhancing its chemical composition and secondary metabolite production, which directly impacts its pharmacological properties. Specifically, optimal light conditions, nutrient solutions, and temperature regulation have been shown to improve the synthesis of bioactive compounds like asiaticoside and madecassoside, which possess significant therapeutic potential for conditions such as inflammation, skin disorders, and neurodegenerative diseases. Thailand's favorable climatic and soil conditions make it an ideal location for cultivating *C. asiatica*, further emphasizing the importance of effective cultivation techniques for both commercial and medicinal purposes. As the demand for *C. asiatica* grows, particularly in the realms of functional foods, nutraceuticals, and skincare, refining cultivation practices is key to meeting the increasing global demand for high-quality, pharmacologically potent products.

From Traditional Medicine to Functional Foods

Centella asiatica (Gotu Kola) has a long-standing history of use in traditional medicine across Asia, where it has been utilized for various health benefits, ranging from enhancing cognitive function to promoting wound healing. Over time, the knowledge of its medicinal properties has expanded, and Centella has gained recognition not only as a therapeutic herb but also as an essential component of functional foods. The journey from traditional medicine to modern functional foods underscores the growing interest in harnessing the plant's bioactive compounds for preventive healthcare and wellness. (Wu et al., 2012)

Traditionally, *C. asiatica* was consumed in various forms, such as fresh leaves, dried preparations, or in tinctures and decoctions. Its medicinal applications were primarily based on

empirical knowledge and indigenous practices, with the plant serving as a remedy for a wide spectrum of ailments. As modern science began to unravel the underlying pharmacodynamics and pharmacokinetics of *C. asiatica*, its therapeutic potential was gradually recognized in a more structured and evidence-based context. (Shen et al., 2019)

In recent decades, there has been a profound shift in the perception of *C. asiatica* from a traditional medicinal herb to a vital constituent in contemporary functional foods and nutraceuticals. As our understanding of its bioactive constituents deepens, particularly through phytochemical analyses and pharmacological investigations, *C. asiatica* has garnered attention not only for its therapeutic applications but also as a key ingredient in functional foods designed to support general wellness and disease prevention. The bioactive compounds found in *C. asiatica*, including asiaticoside, madecassoside, and asiatic acid, have been shown to possess potent neuroprotective, anti-inflammatory, antioxidant, and dermatoprotective properties, making them ideal candidates for functional food formulations. (Gohil et al., 2010)

Of particular interest is the plant's cognitive-enhancing potential. Research has demonstrated that the compounds in *C. asiatica* stimulate neurogenesis, protect neuronal cells from oxidative damage, and inhibit neuroinflammatory pathways, thereby promoting brain health and enhancing cognitive function. (Bylka, 2014) This has led to its inclusion in nutraceuticals targeting age-related cognitive decline, particularly neurodegenerative diseases such as Alzheimer's and Parkinson's. The neuroprotective effects of *C. asiatica* are thought to be mediated through the modulation of key molecular pathways, including the reduction of amyloid-beta plaques and inhibition of the enzyme β-secretase (BACE1), which are critical factors in the pathogenesis of Alzheimer's disease. (Hossain et al., 2021)

In addition to its neuroprotective effects, *C. asiatica* is widely used in both topical and oral formulations for skin health. Its capacity to promote collagen synthesis, accelerate wound healing, and mitigate the effects of oxidative stress has made it an indispensable ingredient in skincare products. The herb's bioactive compounds enhance the synthesis of collagen and extracellular matrix proteins, which are pivotal for maintaining skin elasticity and integrity. These properties have contributed to the herb's popularity in the formulation of anti-aging supplements and topical treatments that promote skin regeneration and mitigate the signs of skin aging, such as wrinkles and fine lines. (Ryall et al., 2022)

The global functional food market has witnessed exponential growth, fueled by an increasing consumer preference for plant-based and natural ingredients that offer health benefits beyond basic nutrition. *C. asiatica* has emerged as a key player in this trend, gaining widespread adoption in various product categories such as cognitive enhancers, anti-aging supplements, and skin health foods. The herb's versatility, coupled with its proven therapeutic efficacy, has catalyzed its inclusion in functional foods aimed at enhancing cognitive performance, reducing stress, and promoting dermal health. The growing emphasis on preventive healthcare and the pursuit of holistic wellness has positioned *C. asiatica* as a sought-after ingredient in the nutraceutical and functional food industries. (Sudhakaran, 2017; Chandrika, 2015)

In particular, the popularity of *C. asiatica* in the wellness sector has surged in markets that prioritize natural, science-backed remedies. As more consumers seek proactive approaches to health maintenance, *C. asiatica* is increasingly featured in functional beverages, capsules, powders, and dietary supplements designed to support mental clarity, skin vitality, and overall health. (Vasanth et al., 2021)

Despite its promising potential, the integration of *C. asiatica* into functional foods and nutraceuticals faces certain challenges. One of the primary issues lies in the variability of bioactive compound concentrations, which can be influenced by factors such as cultivation conditions, geographical location, and harvesting methods. The inconsistency in the levels of key compounds, such as asiaticoside and madecassoside, poses a challenge to standardizing

the plant's potency and ensuring uniformity across commercial products. (Li et al., 2016; Nurlaily et al., 2012)

Moreover, while preclinical and clinical studies have demonstrated the efficacy and safety of *C. asiatica* in various health applications, further research, particularly large-scale, randomized, controlled trials, is needed to substantiate its long-term benefits and potential side effects when consumed as part of a daily functional food regimen. The development of robust clinical evidence will be essential for reinforcing its credibility in the global wellness market. (Hafiz et al., 2020; Ryall, 2022)

In conclusion, the growth and therapeutic properties of *C. asiatica* (Gotu Kola) are significantly influenced by environmental factors such as light, temperature, CO_2 concentration, and nutrient management. Optimizing these factors enhances the production of bioactive compounds like asiaticoside and madecassoside, which are vital for their anti-inflammatory, wound-healing, and neuroprotective effects. Thailand's climate provides an ideal environment for cultivation, supporting both commercial and medicinal use. Refining cultivation practices is essential to meet the growing demand for high-quality *C. asiatica* in modern applications.

Conclusion

The study of Centella asiatica (Gotu Kola) has progressively advanced in understanding its multifaceted role in both traditional medicine and contemporary applications. The bioactive compounds in the plant, particularly asiaticoside and madecassoside, demonstrate diverse pharmacological properties, including wound healing, anti-inflammatory effects, neuroprotection, and cognitive enhancement. These therapeutic potentials have facilitated the transition of *C. asiatica* from a traditional herb to a crucial ingredient in functional foods and modern biomedical products.

Ethnobotanical research has illuminated the cultural and medicinal significance of *C. asiatica* across numerous Asian societies, while modern scientific investigations have continuously validated and expanded upon these traditional applications. This expanding body of knowledge highlights the necessity of optimizing cultivation practices, especially in regions with favorable climatic conditions such as Thailand, to meet the growing global demand for high-quality *C. asiatica*.

The integration of *C. asiatica* into functional foods and nutraceuticals faces certain challenges, notably the variability in concentrations of bioactive compounds. However, these challenges present opportunities for further research to standardize cultivation techniques and ensure consistency in product potency and efficacy. Future studies, particularly large-scale randomized controlled trials, are essential to substantiate the long-term health benefits of this herb and solidify its role in both traditional and modern medical practices. Ongoing research not only enhances our comprehension of the plant's full potential but also opens avenues for discovering novel therapeutic applications and refining cultivation methodologies, ensuring its sustainable use in the future.

References

Arora, R., Kumar, R., Agarwal, A., Reeta, K. H., & Gupta, Y. K. (2018). Comparison of three different extracts of *Centella asiatica* for anti-amnesic, antioxidant and anticholinergic activities: In vitro and in vivo study. *Biomed Pharmacother*, *105*, 1344-1352. https://doi.org/10.1016/j.biopha.2018.05.156

Brinkhaus, B., Lindner, M., Schuppan, D., & Hahn, E. G. (2000). Chemical, pharmacological

and clinical profile of the East Asian medical plant *Centella asiatica*. *Phytomedicine*, *7*(5), 427-448. https://doi.org/10.1016/s0944-7113(00)80065-3

Bylka, W., Znajdek-Awiżeń, P., Studzińska-Sroka, E., Dańczak-Pazdrowska, A., & Brzezińska, M. (2014). *Centella asiatica* in dermatology: An overview. *Phytother. Res.*, *28*, 1117-1124. https://doi.org/10.1002/ptr.5110

Chandrika, U. G., & Prasad Kumarab, P. A. A. S. (2015). Gotu Kola (*Centella asiatica*): Nutritional properties and plausible health benefits. *Adv. Food Nutr. Res.*, *76*, 125-157. https://doi.org/10.1016/bs.afnr.2015.08.001

Changsan, N., Srichana, T., Atipairin, A., & Sawatdee, S. (2023). Wound healing efficacy of a polymeric spray film solution containing *Centella asiatica* leaf extract on acute wounds. *J. Wound Care*, *32*(Suppl. S12), S22-S32. https://doi.org/10.12968/jowc.2023.32.Sup12.S22

Das, A. J. (2011). Review on nutritional, medicinal and pharmacological properties of *Centella asiatica* (Indian pennywort). *J. Biol. Act. Prod. Nat.*, *1*, 216-228. https://doi.org/10.1080/22311866.2011.10719089

Ebau, F., Scano, A., Manca, M. L., Manconi, M., Cabras, V., Pilloni, M., Ennas, G. (2023). *Centella asiatica* extract-SiO_2 nanocomposite: More than a drug-delivery system for skin protection from oxidative damage. *J. Biomed. Mater. Res. A.*, *111*, 300-308. https://doi.org/10.1002/jbm.a.37462

Gohil, K. J., Patel, J. A., & Gajjar, A. K. (2010). Pharmacological review on *Centella asiatica*: A potential herbal cure-all. *Indian J Pharm Sci.*, *72*(5), 546-556. https://doi.org/10.4103/0250-474X.78519

Hafiz, Z. Z., Amin, M., Johari James, R. M., Teh, L. K., Salleh, M. Z., & Adenan, M. I. (2020). Inhibitory effects of raw-extract *Centella asiatica* (RECA) on acetylcholinesterase, inflammations, and oxidative stress activities via in vitro and in vivo. *Molecules*, *25*(4), 892. https://doi.org/10.3390/molecules25040892

Hein, Z. M., Gopalakrishna, P. K., Kanuri, A. K., Thomas, W., Hussan, F., Naik, V. R., Shantakumari, N., Che Ramli, M. D., Mohd Moklas, M. A., Che Mohd Nassir, C. M. N., & Vishnumukkala, T. (2025). *Centella asiatica*: Advances in Extraction Technologies, Phytochemistry, and Therapeutic Applications. *Life, 15*(7), 1081. https://doi.org/10.3390/life15071081

Hossain, S., Urbi, Z., Karuniawati, H., et al. (2021). Andrographis paniculata (*Burm. f.*) wall. Ex Nees: An updated review of phytochemistry, antimicrobial pharmacology, and clinical safety and efficacy. *Life (Basel)*, *11*(4), 348.

Jan, R., Asaf, S., Numan, M., Lubna, & Kim, K.-M. (2021). Plant secondary metabolite biosynthesis and transcriptional regulation in response to biotic and abiotic stress conditions. *Agronomy*, *11*, 968. https://doi.org/10.3390/agronomy11050968

Kuo, Y.-S., Chien, H.-F., & Lu, W. (2012). *Plectranthus amboinicus* and *Centella asiatica* cream for the treatment of diabetic foot ulcers. *Evid.-Based Complement. Altern. Med.*, *2012*, 418679. https://doi.org/10.1155/2012/418679

Li, S. Q., Xie, Y. S., Meng, Q. W., Zhang, J., & Zhang, T. (2016). Neuroprotective properties of madecassoside from *Centella asiatica* after hypoxic-ischemic injury. *Pak J Pharm Sci.*, *29*(6), 2047-2051.

Nurlaily, A., Noor Baitee, A. R., & Musalmah, M. (2012). Comparative antioxidant and anti-inflammatory activity of different extracts of Centella asiatica (L.) Urban and its active compounds, asiaticoside and madecassoside. *Med & Health*, *7*(2), 62-72.

Paocharoen, V. (2010). The efficacy and side effects of oral *Centella asiatica* extract for wound healing promotion in diabetic wound patients. *J. Med. Assoc. Thai.*, *93*(Suppl. S7), S166-S170.

Prakash, V., Jaiswal, N., & Srivastava, M. (2017). A review on medicinal properties of

Centella asiatica. *Asian J. Pharm. Clin. Res.*, *10*(10), 69-74. https://doi.org/10.22159/ajpcr.2017.v10i10.20760

Ruszymah, B. H. I., Chowdhury, S. R., Manan, N. A. B. A., Fong, O. S., Adenan, M. I., & Saim, A. B. (2012). Aqueous extract of *Centella asiatica* promotes corneal epithelium wound healing in vitro. *J. Ethnopharmacol.*, *140*, 333-338. https://doi.org/10.1016/j.jep.2012.01.023

Ryall, C., Chen, S., Duarah, S., & Wen, J. (2022). Chitosan-based microneedle arrays for dermal delivery of *Centella asiatica*. *Int. J. Pharm.*, *627*, 122221. https://doi.org/10.1016/j.ijpharm.2022.122221

Shen, X., Guo, M., Yu, H., Liu, D., Lu, Z., & Lu, Y. (2019). Propionibacterium acnes related anti-inflammation and skin hydration activities of madecassoside, a pentacyclic triterpene saponin from *Centella asiatica*. *Biosci Biotechnol Biochem.*, *83*(3), 561-568. https://doi.org/10.1080/09168451.2018.1547627

Sudhakaran, M. (2017). Botanical pharmacognosy of *Centella asiatica* (Linn.) urban. *Pharmacogn. J.*, *9*(4), 546-558. https://doi.org/10.5530/pj.2017.4.88

Sun, B., Wu, L., Wu, Y., Zhang, C., Qin, L., Hayashi, M., ... & Liu, T. (2020).Therapeutic potential of *Centella asiatica* and its triterpenes: A review. *Front Pharmacol.*, *11*, 568032. https://doi.org/10.3389/fphar.2020.568032

Torbati, F. A., Ramezani, M., Dehghan, R., Amiri, M. S., Moghadam, A. T., Shakour, N., Elyasi, S., Sahebkar, A., & Emami, S. A. (2021). Ethnobotany, phytochemistry and pharmacological features of *Centella asiatica*: A comprehensive review. *Adv. Exp. Med. Biol.*, *1308*, 451-499. https://doi.org/10.1007/978-3-030-64872-5_25

Vasanth, S., Mohanraj, R. S., & Mandal, J. (2021). In-vitro study of the effect of *Centella asiatica* on cholera toxin production and the gene expression level of ctxA gene in *Vibrio cholerae* isolates. *J Ethnopharmacol.*, *279*, 113930. https://doi.org/10.1016/j.jep.2021.113930

Witkowska, K., Paczkowska-Walendowska, M., Plech, T., Szymanowska, D., Michniak-Kohn, B., & Cielecka-Piontek, J. (2023). Chitosan-based hydrogels for controlled delivery of asiaticoside-rich *Centella asiatica* extracts with wound healing potential. *Int. J. Mol. Sci.*, *24*(24), 17229. https://doi.org/10.3390/ijms242417229

Wu, F., Bian, D., Xia, Y., Gong, Z., Tan, Q., Chen, J., & Dai, Y. (2012). Identification of major active ingredients responsible for burn wound healing of *Centella asiatica* herbs. *Evid Based Complement Alternat Med.*, *2012*, 848093. https://doi.org/10.1155/2012/848093

Yang, L., Wen, K.-S., Ruan, X., Zhao, Y.-X., Wei, F., & Wang, Q. (2018). Response of plant secondary metabolites to environmental factors. *Molecules*, *23*, 762. https://doi.org/10.3390/molecules23040762