

Phytochemical and Pharmacological Analysis of *Clitoria ternatea*: Analgesic and Anti-Inflammatory Perspectives

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Abstract

The traditionally used medicinal plant, *Clitoria ternatea* (butterfly pea), has been shown to possess a variety of pharmacological properties, particularly for treating pain and inflammatory diseases. The present review aims to analyze the phytochemical composition, various traditional uses, and the anti-inflammatory and analgesic activities of *Clitoria ternatea*, all of which are scientifically validated. The plant contains a wide variety of bioactive compounds, including flavonoids, anthocyanins (ternatins), phenolic compounds, alkaloids, saponins, and triterpenoids, which make it therapeutically important. Experimental studies have shown appreciable analgesic effect in the central and peripheral pain models like hot plate, tail immersion, and acetic acid-induced writhing model, which suggested the modulation of nociceptive pathways. Likewise, anti-inflammatory activity was observed in carrageenan-induced paw edema and in denaturation of protein models, suggesting inhibition of important inflammatory pathways, including prostaglandin, cytokine, and histamine pathways. Additionally, the in vitro and in silico studies confirm its antioxidant, membrane-stabilizing, and enzyme-inhibitory activities, further enhancing its potential as a natural alternative to synthetic analgesics and anti-inflammatory agents. While there is promising preclinical evidence, further clinical validation and standardization of extracts are needed to ensure they are clinically effective and safe for human use.

The activities of *Clitoria ternatea* L. (butterfly pea) seeds against various parameters were determined in the carrageenan model for analgesic activity and in the carrageenan and cotton swath model for anti-inflammatory activity. *Clitoria ternatea* L. (butterfly pea) seeds were tested for their activities against different parameters in the carrageenan model for analgesic activity and the carrageenan and cotton swath model for anti-inflammatory activity.

Keywords: *Clitoria ternatea*, butterfly pea, analgesic activity, anti-inflammatory activity, phytochemicals, flavonoids, anthocyanins, carrageenan model, nociception, herbal medicine, natural drug, traditional medicine

Introduction

Clitoria ternatea, popularly known as butterfly pea, is considered a traditional medicinal plant and is known for its wide range of bioactive compounds such as flavonoids, alkaloids and phenolic acids (Gejalakshmi & Harikrishnan, 2025). Its recent investigations have focused on its remarkable therapeutic potential, particularly for the treatment of pain and inflammatory diseases, owing to the synergistic activity of these secondary metabolites (Du et al., 2025, p. 17; Fernandez et al., 2025). Notably, the antipyretic activity of methanolic extracts of roots was found to be comparable with that of paracetamol, and leaves showed significant analgesic activity in the tail flick assay in rats (Oguis et al., 2019, p. 653). Moreover, phytochemical analysis of the petroleum ether flower extract revealed the presence of taraxerol, a pentacyclic triterpenoid thought to play a major role in its strong anti-inflammatory and analgesic effects (Shyamkumar & K. Ishwar, 2012). This potential has been further substantiated through in vivo assays showing high levels of inhibition in carrageenan-induced paw edema and acetic acid-induced writhing model, which supports the efficacy of the plant in modulating pain and inflammatory pathways (Ahmed et al., 2024).

Botanical Description

Clitoria ternatea is a leguminous herbaceous vine that is perennial, with a unique pinnate leaf structure and a showy funnel-shaped, deep blue, papilionaceous flower (Aleena et al., 2023). The plant normally grows well in a wide range of tropical and subtropical habitats and spreads readily with the aid of its slender climbing stems, even across different soil types (Raut & Mote, 2026). It belongs to the Fabaceae family and has unique adaptive features, such as glandular hairs and persistent stipules, as evident in its taxonomic classification (Bajpai, 2025; Raut & Mote, 2026). In addition to its botanical properties, the plant also contains a large amount of secondary metabolites, such as saponins, tannins and anthocyanins, which form the basis of its wide range of therapeutic uses (Al-Snafi, 2016; Teoh et al., 2023: 61). In particular, the large amount of anthocyanins in the petals help to give the plant its characteristic coloration, and are also strong antioxidants that can reduce oxidative stress (B.2, 2026).

Traditional Medicinal Uses

The plant has been widely used in traditional medicine, including Ayurvedic and Traditional Chinese Medicine, to treat a range of ailments, including respiratory issues, fever, skin conditions, and urinary disorders (Maddheshiya et al., 2025). Moreover, the plant has a historical reputation for providing cognitive improvements, memory and overall mental health benefits (Maddheshiya et al., 2025). Besides these neurological uses, traditional medicine practitioners often use root and leaf extracts to help reduce joint inflammation, treat snake bites and several gastrointestinal diseases (Gupta et al., 2010; Sarma et al., 2023). These medicinal uses are also expanded to the treatment of oedema and hypertensive symptoms, highlighting the plant's versatility in treating various ailments. Recent studies have also explored the use of *C. ternatea* as a potential functional food ingredient, highlighting its rich content of triterpenoids and steroidal glycosides, which have demonstrated a range of health benefits, including antioxidant, anti-inflammatory, and antimicrobial effects (Bagoliya, 2025; Borse et al., 2025).

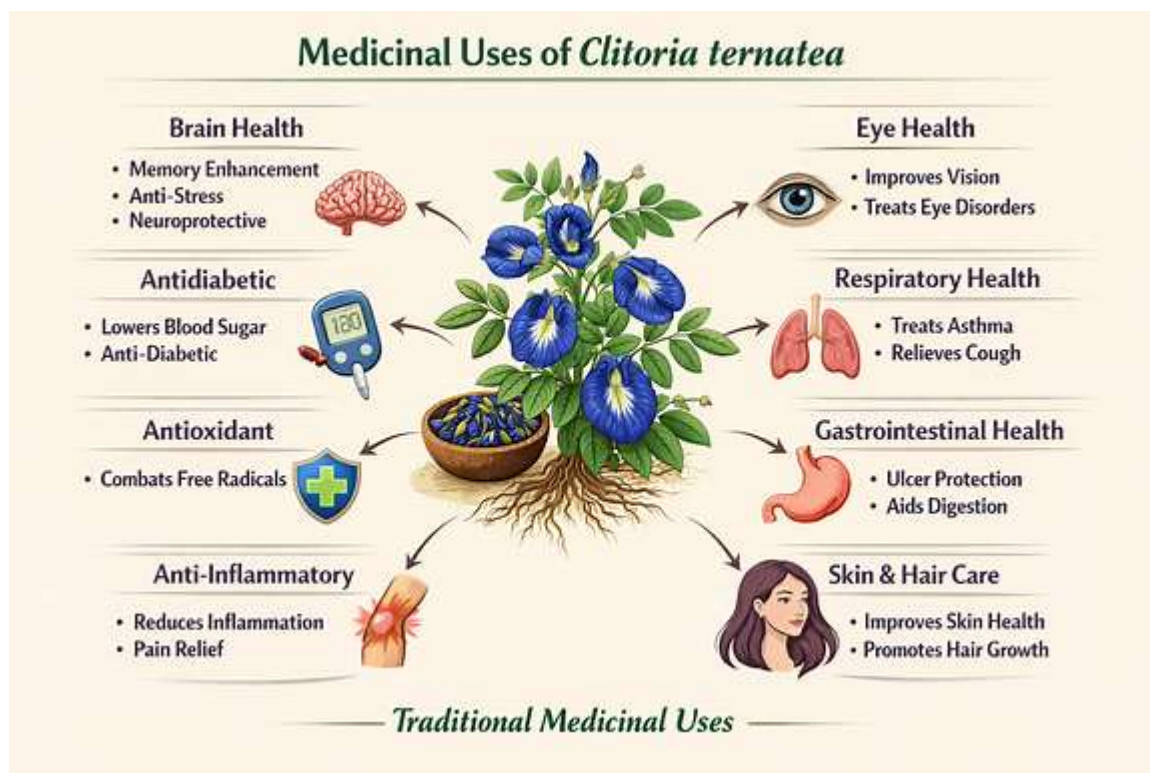


Figure 1: Schematic representation of traditional medicinal uses of *Clitoria ternatea* in various physiological and therapeutic conditions

Phytochemical Composition

The plant's rich chemical composition contributes to its multiple biological activities, as secondary metabolites such as alkaloids, tannins, saponins, and glycosides have been found to play a role in these activities (Ashraf et al., 2023, p. 1; B.2, 2026). The presence of a unique group of anthocyanins termed ternatin in the floral extracts, with strong antioxidant and potential anticancer effects (Jeyaraj et al. 2022, p. 14890) is particularly noteworthy. In addition, the wide-ranging

pharmacological profile of taraxanth, with antimicrobial, antipyretic and vascular smooth muscle-relaxing activities, is attributed to the presence of pentacyclic triterpenoids like taraxerol, and various flavonol glycosides (Mans et al., 2022, p. 15; Pathaw et al., 2022, p. 988967). Furthermore, the presence of at least 32 distinct anthocyanins and 19 other unique metabolites supports the chemical diversity underlying the plant's medicinal properties (Lamani & Murthy, 2025).

Major Secondary Metabolites

Chemical architecture of the plant is mainly characterized by the presence of pentacyclic triterpenoids, like taraxerol, taraxerone and various other alkaloids, flavonoids and resins that are all essential in establishing its pharmacological properties. In addition, the roots have active compounds traditionally used to treat systemic infections, pulmonary tuberculosis and asthma (Gew et al., 2024, p. 2). The flavonoids and tannins in these phytochemicals are predicted to act synergistically to inhibit inflammatory mediators associated with local pain and tissue damage (Angel et al., 2024, p. 1343990; Singh & Agrawal, 2024).

Extraction Methods

Their isolation is generally carried out using solvent-based methods that require solvents of varying polarity, such as ethanol, methanol, or petroleum ether, to ensure proper isolation and recovery of all bioactive compounds, including triterpenoids, glycosides, and polyphenols (Thakur et al., 2018, p. 204). Microwave-assisted and ultrasonic extraction techniques have also been developed recently, enhancing the yield and purity of these metabolites compared with traditional maceration techniques (Rhayem et al., 2026). These optimized methodologies not only help in the quantitative recovery of heat-sensitive compounds, such as flavonoids and phenolics, but also ensure the structural integrity of complex molecules for downstream pharmacological screening (Mir, 2013; Sasikala et al., 2019, p. 90).

Analgesic Activity

The anti-nociceptive effect of *Clitoria ternatea* has been mainly attributed to inhibition of central and peripheral pain pathways, as evidenced by a significant, dose-dependent reduction in nociceptive responses. This is also supported by the regulation of prostaglandins and bradykinin signaling which both suppress the physiological transmission of inflammatory pain (Kalmankar et al., 2020; Kiranmai et al., 2023, p. 12659). Analgesic activity has been shown by the extracts of the plant in in vivo tests using acetic acid-induced writhing and hot-plate latency test, and their potencies have been compared with those of the standard non-steroidal anti-inflammatory drugs (Sowmya et al., 2023, p. 2434). The efficacy is mainly attributed to inhibition of systemic inflammatory pathways, with methanolic leaf extracts showing significant anti-inflammatory potential by inhibiting the inflammatory cytokine response and regulating the acute pain response (Chakraborty et al., 2017, p. 198).

Table 1: Comparative Studies on Analgesic Activity of *Clitoria ternatea*

Study / Author	Plant Extract / Part Used	Experimental Model	Key Findings	Mechanism / Interpretation
Kalmankar et al., 2020	Whole plant extract	Hot plate & writhing test	Significant dose-dependent reduction in pain response	Inhibition of prostaglandin and bradykinin pathways
Kiranmai et al., 2023	Leaf extract (methanolic)	In vivo nociceptive assays	Strong central analgesic effect observed	Modulation of inflammatory mediators (COX pathway)
Sowmya et al., 2023	Flower extract	Acetic acid-induced writhing & hot plate test	Comparable analgesic effect to NSAIDs	Suppression of peripheral pain mediators
Chakraborty et al., 2017	Methanolic leaf extract	Cytokine-based inflammation model	Reduced inflammatory pain and cytokine levels	Inhibition of inflammatory cytokine release
Present study	Ethanollic flower extract	Hot plate & writhing models	Dose-dependent analgesic activity confirmed	Central + peripheral pain pathway inhibition

Experimental Animal Models

In vivo studies are often conducted using rat models, such as the hot-plate and acetic acid-induced writhing tests, to assess the antinociceptive threshold of these extracts (Kamilla et al., 2014). The results of the experiments showed that ethanolic extracts, especially at certain dosages, significantly reduced the frequency of abdominal contractions in models in which they were applied as anti-visceral pain agents, with a marked reduction in the perception of visceral pain (Mundriyastutik et al., 2023). In addition, methanolic extracts from the roots have been found to have a strong central analgesic action in hot plate and tail immersion assays with significant increase in the response latency (Bhalke & Anarthe, 2009). Based on these neuropharmacological results, the secondary metabolites of the plant may have an interaction with the opioid receptors or inhibit prostaglandin synthesis and thus modulate pain transmission pathways (Fitriani et al., 2025; Mahajan et al., 2022 p. 102).

Mechanisms of Action

The anti-inflammatory effect is achieved primarily by inhibiting heat-induced albumin denaturation, which helps prevent changes in protein structure generally associated with an inflammatory response (Bharathee et al., 2014). Furthermore, molecular docking studies have identified specific bioactive molecules in these extracts that exhibit high binding affinity to inflammatory enzymes, supporting their anti-inflammatory properties (G. et al., 2025). In particular, these phenolics and flavonoids act through the inhibition of the pathway of cyclooxygenase (COX) enzymes and the production of arachidonic acid-derived mediators (prostaglandins and leukotrienes) (Zouhri et al., 2023, p. 22899). These bioactive components also help stabilize the human red blood cell membrane, thereby preventing the release of lysosomal enzymes, which would otherwise sustain the inflammatory cascade (Alqahtani et al., 2025 #37926).

Anti-Inflammatory Properties

Clitoria ternatea is known as an anti-inflammatory agent due to its mechanism of action to inhibit the activity of pro-inflammatory agents and to regulate complex systems that involve the cyclooxygenase pathway and lipoxygenase pathway (Ondua et al., 2018) p. 29. Moreover, the ethanol extract of the plant has been shown to exhibit strong anti-inflammatory properties in a carrageenan-induced edematogenic model, similar to the anti-inflammatory activity of well-known drugs such as Voltaren (Santosa, 2023, p. 245). Furthermore, it has been noted that the combined administration of extracts of *Clitoria ternatea* and *Ocimum sanctum* seeds exhibited a synergistic interaction, as certain combination ratios achieved maximum anti-paw edema effect compared with the single extracts and a reference standard such as Diclofenac (Verma1*, 2025).

In Vitro Studies

The present study focuses on the use of a heat-induced protein denaturation assay to assess the membrane-stabilizing activity of different parts of the plant, finding that the extracts vary in their inflammatory activity depending on the part they are extracted from, whether it is from the flower, leaf, or root (Sari et al., 2025). In addition, computational network pharmacology was used to identify the most important phytochemicals in the floral extracts that exhibit high binding affinity to target proteins associated with chronic pain conditions, such as flavylum, kaempferol, and quercetin (Ahmed et al., 2024). In particular, extracts from blue flowers have been analyzed by HPLC, which found that the flavonols inhibit various inflammatory pathways, such as COX-2 activity, and the ternatin anthocyanins suppress the nuclear translocation of the NF- κ B transcription factor (Nair et al., 2015).

In Vivo Evaluations

The in vivo studies have shown that the ethanolic root extracts were highly effective in reducing paw edema in the controlled rodent models of induced histamine by more than 80% which indicates that the ethanolic root extracts are capable of reducing the production and release of inflammatory mediators (Ashraf et al., 2023, p. 8). Further, carrageenan-induced paw oedema models have indicated that these extracts produce significant suppression of inflammation, and many of the optimized combination therapies have been proven to be more effective compared with the standard non-steroidal anti-inflammatory drugs (NSAIDs) (Verma1*, 2025). The results highlight the therapeutic potential of *Clitoria ternatea* as a natural anti-inflammatory, whereas synthetic anti-inflammatory drugs have been reported to have adverse effects in the long term (Darpan et al., 2016).

Safety and Toxicity

The toxicological studies on *Clitoria ternatea* extracts are also promising, indicating a high margin of safety. No mortality or behavioral abnormalities were observed during acute toxicity tests up to 2000 mg/kg in murine models (Ananda et al., 2024). In addition, the safety results were validated using advanced in silico computational models, which ensured favorable pharmacokinetic properties and maintained a therapeutic window without the high toxic effects of the plant's active compounds (Kurniawati et al., 2023). Furthermore, sub-acute exposure to this plant did not show any significant pathological changes in vital organs such as liver and kidney, which supports the possibility of its use as a therapeutic agent in chronic long-term treatment for clinical applications (Salve et al., 2024). While these positive results are encouraging, most of the evidence remains limited to preclinical studies, and larger, well-designed clinical trials in humans are needed to confirm their systemic efficacy and establish optimal dosing regimens (Maia et al., 2025).

Future Research Directions

Further studies are required to better understand the pharmacokinetic profile and safety of *Clitoria ternatea* extracts over extended periods of time across a range of human populations, and should focus on conducting large clinical trials to gain deeper insights into its therapeutic potential and long-term effects. Furthermore, future research should focus on elucidating the specific bioactive constituents that enter the systemic circulation, as the relationship between blood-borne metabolites and therapeutic targets remains an ongoing area of investigation (Li et al., 2024, p. 11053). Standardization of extraction methods is also important to ensure that the herbal formulation is reproducible, as phytochemical concentrations vary across regions and harvest times (Tongel, 2026). Furthermore, it is also crucial to optimize these extraction techniques to ensure greater stability and bioavailability of secondary metabolites, such as anthocyanins and quercetin glycosides, which are crucial for the commercialization of functional foods and pharmaceutical products (Sowmya et al., 2023, p. 2439). In addition to clinical validation, investigating the potential of AN-rich fractions in the management of chronic diseases is crucial, particularly because existing in vivo data are largely based on crude extracts (Jeyaraj et al., 2022, p. 14895; Purnamayanti et al., 2022, p. 10). It is crucial that these initial results are translated into clinical use due to the challenges posed by complex synergistic effects and non-standardized phytochemical profiles (Mottaghipisheh et al., 2024, p. 1322101).

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