

Exploring the Hepatoprotective Potential of *Clitoria ternatea* L.: A Comprehensive Review of Its Phytochemistry, Pharmacological Activities, and Future Prospects

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ABSTRACT

Hepatic inflammation is a major contributor for the progression of liver disease including non-alcoholic fatty liver disease (NAFLD), alcoholic liver disease, viral hepatitis, fibrosis, cirrhosis and hepatocellular cancer. Under hepatic inflammation, the inflammatory response plays a central role in hepatocyte injury due to oxidative stress and chronic inflammatory responses, highlighting the need for effective therapeutic approaches. *Clitoria ternatea* L. (butterfly pea), a medicinal plant known for its ornamental beauty and medicinal value had been recently gaining increasing interest towards its diverse phytochemical constituents showing pharmacological properties. This review summarizes the phytochemistry, pharmacological activities and most importantly how *Clitoria ternatea* could be a potential therapeutic drug with emphasis on its role of management of hepatic inflammation. The plant is rich in bioactive phytochemicals, including anthocyanins, flavonoids, phenolic compounds, and cyclotides, which exhibit antioxidant, anti-inflammatory, and hepatoprotective activities. Experimental studies have demonstrated that *Clitoria ternatea* extracts reduce oxidative stress, improve liver function biomarkers such as alanine aminotransferase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (ALP), and bilirubin, and restore normal liver histopathology in various animal models of hepatotoxicity. Despite these promising findings, current evidence is largely limited to preclinical studies, with insufficient clinical data to confirm efficacy and safety in humans. Future research should focus on standardized herbal formulations, well-designed clinical trials, and advanced drug delivery systems to enhance the bioavailability and therapeutic potential of *Clitoria ternatea* in the management of hepatic inflammation.

Keywords: *Clitoria ternatea*; hepatic inflammation; hepatoprotective activity; phytochemicals; oxidative stress; antioxidants; liver disease.

Introduction

The liver is the second largest organ of the human body and it is the power house of the body. It is involved in almost all of the physiological processes such as breaking down of nutrients like carbohydrates, proteins and lipids, storing energy in the form of glycogen, vitamins, and minerals. It is also involved in the synthesis of plasma proteins and detoxification of endogenous and exogenous toxic substances (Kumar et al., 2025). Almost all the xenobiotics and drugs that are ingested by the human body pass through the liver for metabolism. The liver produces certain detoxifying enzymes called cytochrome P450 which can convert xenobiotics into active metabolites (Kumar et al.,

2020). (Kumar et al., 2025) Liver diseases are one of the major causes of death in the world, about two million deaths are to be noted every year (Asrani et al., 2019). The liver can be damaged from drug-induced injury, excessive alcohol intake, viral infections, toxins, metabolic syndrome such as obesity and diabetes, and autoimmunity (WHO, World Health Organization, 2017). There are about 40% of cases of acute liver failure, caused by drug-induced liver injury. In western countries, acetaminophen overdose is the leading cause of drug-induced liver injury. Chronic alcohol intake, Hepatitis A to E viral infection, and non-alcoholic fatty liver disease are also major contributors to liver damage across the globe. (WHO, World Health Organization – Global Hepatitis Report, 2017)

Liver injuries can be caused by various mechanisms but they all follow similar pathological processes. These pathological processes mainly comprise of oxidative stress that leads to the generation of highly reactive oxygen species. There is also the involvement of inflammatory pathways that trigger the release of various pro-inflammatory cytokines such as $\text{TNF-}\alpha$, $\text{IL-1}\beta$, and IL-6 which lead to liver damage. Oxidative stress leads to lipid peroxidation of cell membranes causing damage to the proteins, lipids, and DNA (Michalak & Cichoż-Lach, 2014). This leads to cell death through necrosis and apoptosis. Accumulation of oxidized cellular debris causes activation of Kupffer cells resulting in the release of pro-inflammatory cytokines. The cytokines released are responsible for the cause of damage to the parenchymal cells and disruptions to the normal structure of the liver.

Current pharmacological management of liver diseases has various shortcomings including adverse effects, high cost of therapy, and lack of effectiveness in halting the disease progression. Therefore, there is need for more effective and affordable pharmacological interventions. There are various plants containing phytochemical compounds with hepatoprotective effects. Many plants are currently being investigated for their efficacy in the management of liver diseases (Shawon & Reyda, 2024). This article study reviews the current knowledge on the phytochemical composition of *Clitoria ternatea* and its potential therapeutic pharmaceutical applications on liver inflammation and treatment. This review will highlight the possible biochemical mechanisms by which *Clitoria ternatea* exerts its protective effects on the liver and the current evidence for its medicinal use in liver inflammation (Phruksanan et al., 2014). The review will also discuss the challenges to be faced in the development of *Clitoria ternatea* as a hepatoprotective drug.

2. Pathophysiology of Hepatic Inflammation

Hepatic inflammation is a type of protective response that is triggered when the liver is being exposed to infectious pathogens, toxins, alcohol, metabolic byproducts, and the drugs that are capable of damaging the liver cells (Pinzani & Parola, 2018). The inflammatory response helps in eliminating the injuring medium and by repairing the liver tissues. However, in some cases, the inflammatory response can persist causing liver damage and other complications. Some of the common mechanisms which is involved in liver inflammation include oxidative stress, disruption of normal mitochondrial functions, and release of pro-inflammatory cytokines that cause tissue damage and disturbs the normal liver function.

One of the main reasons contributing to the liver damage is the increased production of reactive oxygen species (ROS) which leads to oxidative stress. Oxidative stress is caused when an imbalance is raised between ROS production and the antioxidant defense system (Michalak & Cichoż-Lach, 2014). ROS such as superoxide anion, hydroxyl radicals, and hydrogen peroxide are highly reactive and cause damage to lipids, proteins, and DNA in the liver cells. Conditions such as acetaminophen toxicity, alcohol abuse, carbon tetrachloride poisoning, viral hepatitis, and metabolic syndrome can increase ROS production in the liver. ROS can also cause disruption of normal mitochondrial functions and apoptosis of liver cells (Michalak & Cichoż-Lach, 2014). The damage caused by ROS leads to release of danger-associated molecular patterns (DAMPs) from the damaged liver cells. The DAMPs trigger an inflammatory response by activating Kupffer cells. Activated Kupffer cells release pro-inflammatory cytokines such as tumor necrosis factor- α ($\text{TNF-}\alpha$), Interleukin ($\text{IL-1}\beta$), and IL-6 which lead to liver inflammation. Inflammatory cytokines disrupt normal liver functions by inducing apoptosis and necrosis of liver cells. This leads to extensive damage of liver tissues and impaired liver function (Kumar et al., 2025).

Various inflammatory signaling pathways are involved in liver inflammation. Nuclear factor-kappa B (NF- κ B) is a key regulator of the inflammatory response in the liver. NF- κ B is activated by a variety of stimuli including infection and toxins. Activation of NF- κ B leads to increased production of pro-inflammatory cytokines, adhesion molecules, and chemokines that contribute to liver damage. NF-E2 related factor 2 (Nrf2) pathway regulates the antioxidant defense system in the liver (Michalak & Cichoż-Lach, 2014). Activation of Nrf2 pathway leads to increased production of antioxidant enzymes thus countering ROS damage. Persistent oxidative stress and inflammatory response causes activation of hepatic stellate cells which leads to fibrosis and other liver complications (Pinzani & Parola, 2018). Therefore, drugs showing potential towards oxidative stress and inflammatory responses are likely to be successful in the management of liver diseases.



Figure 1: of Clitoria Ternatea

3. Botanical Description and Uses of Clitoria Ternatea

Clitoria ternatea is a perennial herb belonging to the family of Fabaceae. The plant grows abundantly in the tropical and sub-tropical regions of Asia, Australia, Africa and the Americas. They are very prominent and found in India throughout the country, specifically in the southern states such as Kerala, Tamilnadu, Andhra Pradesh, Telengana, Karnataka. They are widely known for their ornamental beauty and their medicinal value. The botanical description of the plant involves the distinctive feature of vivid deep blue flowers. The structure of the flower is axillary and zygomorphic. The dimensions are about 4 cm in length and 3 cm in width. The shape of the flower is described as conch-shaped, giving rise to its Sanskrit name Shankupushpam, and their resemblance to the human female genitals is the basis for the genus name Clitoria. The plant produces flat, linear-oblong pods in about 5 to 13 cm in length. Each pod typically holds six to ten seeds; the seeds are rich in fatty acids, primarily oleic acids. The plant consists of terminal leaflets and two to four pairs of imparipinnate leaflets. The leaves are oval to elliptic in shape and measure about 6.5 cm in length and 4 cm in width (Jeyaraj et al., 2024).

In Ayurveda, this plant is referred to as Aparajita or Shankupushpam. In this system of medicine, the plant is used as a brain tonic and memory enhancer and also for the treatment of anxiety, fevers, inflammation, and stomach ulcers. It has also been used as a diuretic and an aphrodisiac. Due to the high content of anthocyanins, this plant is used as a food dye, additive, and in making of caffeine-free herbal teas. Other traditional systems of medicine have also used different parts of this plant to treat a wide range of ailments including skin diseases, coughs, colds, infections, and urinary problems (Jeyaraj et al., 2024).

Due to the wide range of phytochemical constituents present in this plant, it has been caught by many interests of many researchers with its medicinal value. Many of the phytochemicals found in this plant have been shown to have pharmacological activities. The most important among these phytochemicals are: anthocyanins, flavonoids, phenolic compounds, cyclotide, triterpenoids, alkaloids, saponins, and phytosterols (Jeyaraj et al., 2024). This plant has been used in traditional medicine for various health problems. Some of the phytochemicals present in this plant have shown antioxidant, anti-inflammatory, antimicrobial, antidiabetic, and neuroprotective properties. It has also been shown to

have hepatoprotective properties. The therapeutic potential of this plant in the management of liver inflammation is discussed in this paper. (Oguis et al., 2019) (Royal Botanic Gardens)

Common Name	Botanical Part	Phytochemical	Pharmacological	Dosage and Form	Traditional Medicine	Geographic Distribution
Butterfly Pea, A	Flowers	Anthocyanins	Antioxidant, Anti-inflammatory	1–2 g aqueous	Ayurvedic medicine	Native to Equatorial Africa
Butterfly Pea, A	Roots	Triterpenoids	Nootropic (Memory enhancing)	100–500 mg/kg	Ayurvedic medicine	Tropical regions
Butterfly Pea, A	Leaves	Alkaloids, Flavonoids	Hepatoprotective	100–500 mg/kg	Ayurvedic and folk medicine	Tropical and subtropical regions
Butterfly Pea, A	Seeds	Proteins (Finotins)	Anticancer (Cytotoxic)	400 mg/kg (infusion)	Ayurvedic brain tonic	Tropical Asia, Africa
Butterfly Pea, E	Pods and Fruits	Carbohydrates, Triterpenoids	Hepatoprotective	250–500 mg/kg	Memory enhancing	Native to tropical regions

4. Phytochemical Composition of *Clitoria Ternatea*

Each and every part *Clitoria ternatea* such as flowers, leaves, roots, and seeds contain various a phytochemical constituents that have beneficial effects on human health. Some of the phytochemicals present in this plant have been extensively studied and they include anthocyanins, flavonoids, phenolic compounds, cyclotides, triterpenoids, and alkaloids. The other phytochemical constituents that have been identified in this plant and which may have potential health benefits are saponins and phytosterols. The various phytochemicals found in this plant have antioxidant, anti-inflammatory, antimicrobial, neuroprotective, antidiabetic, and hepatoprotective effects. This plant is therefore effective in the management of various health problems including liver inflammation (Oguis et al., 2019). (Jeyaraj et al., 2024)

4.1 Anthocyanins (Ternatins)

Anthocyanins are water-soluble pigments that are responsible for the intense blue color of the flowers of *Clitoria ternatea*. The major anthocyanins found in this plant are the ternatins. These compounds have potent antioxidant effects (Oguis et al., 2019). They are also effective in reducing inflammation. Ternatins have great medicinal importance since they are easily absorbed in the body and they have excellent stability. The mentioned properties make them effective in the synthesis of pharmaceuticals. Anthocyanin especially Ternatins have been used in the treatment of various health problems. (Kazuma et al., 2003) (Terahara et al., 1998)

4.2 Flavonoids

Flavonoids are major components of *Clitoria ternatea*. Common Flavonoids that has been found and identified in this plant include quercetin, kaempferol, myricetin, and rutin. Flavonoids have potent antioxidant properties since they are able to donate electrons and neutralize free radicals. They additionally help in reducing oxidative stress by stimulating the production of endogenous antioxidant enzymes such as superoxide dismutase (SOD), catalase (CAT), and glutathione (GSH). Flavonoids reduce liver inflammation by inhibiting the production of pro-inflammatory cytokines such as tumor necrosis factor-alpha (TNF- α), interleukin (IL)-1 β , and IL-6. They also help in the prevention of liver damage since they reduce lipid peroxidation of cellular membranes. Flavonoids are therefore effective in the management of liver inflammation (Michalak & Cichoż-Lach, 2014).

4.3 Phenolic Compounds

Phenolic compounds are phytochemical constituents of *Clitoria ternatea* that have potent antioxidant properties (Oguis et al., 2019). They help in reducing the harmful effects of reactive oxygen species (ROS) by acting as reducing agents and scavenging free radicals. They also help to reduce lipid peroxidation of cellular membranes thereby reducing cellular damage. Phenolic compounds help in reduction of inflammatory responses and microbial infections in the liver. Therefore, these compounds are useful in the management of liver inflammation.

4.4 Cyclotides

Cyclotides are also called as cliotides. They are heat stable cyclic peptides which provides a natural defense system. These compounds have unique structural properties that make them highly resistant to enzymatic and acidic degradation. Cyclotides have potent antimicrobial properties and they are effective in the treatment of bacterial infections. They also have potent antiviral, anti-inflammatory, and insecticidal properties. Hence they are potentially effective in the treatment of hepatic damage

4.5 Other Phytochemical Constituents

In addition to the above-mentioned phytochemical constituents, *Clitoria ternatea* also contains triterpenoids, alkaloids, saponins, and phytosterols. these compounds also add to be having antioxidant, anti-inflammatory, antimicrobial, and anticancer properties. They also help in protecting the liver against damage. Although these constituents have not been studied extensively, they might contribute to the medicinal value of this plant.

5. Pharmaceutical Potential Of *Clitoria Ternatea* In Hepatic Inflammation

It has been established that the phytochemical constituents of *Clitoria ternatea* have potent antioxidant, anti-inflammatory, and hepatoprotective properties. Many of the phytochemical constituents of this plant have been studied extensively and they are capable of reducing oxidative stress, reducing inflammatory responses, and preventing liver damage. The current review discusses the medicinal potential of this plant in the management of liver inflammation. (Shawon & Reyda, 2024)

5.1 Antioxidant Activity

Oxidative stress plays a major role in liver damage since it causes lipid peroxidation of cell membranes (Asrani et al., 2019). This leads to disruption of cell membranes resulting in liver damage and inflammation. The phytochemical constituents of *Clitoria ternatea* are potent antioxidants and they help in eliminating free radicals that cause oxidative stress. For instance, anthocyanins inhibit the production of free radicals thus reducing oxidative stress. Flavonoids and phenolic compounds also counteract the harmful effects of free radicals. Various studies have shown that extract of this plant increases the activity of endogenous antioxidant enzymes such as SOD, CAT, and GSH while decreasing the levels of lipid peroxidation products such as malondialdehyde (MDA). The antioxidant activity of this plant extract prevents cellular damage and death thus reducing levels of hepatic enzymes such as Alanine aminotransferase (ALT), Aspartate aminotransferase (AST), and Alkaline phosphatase (ALP) in the blood.

5.2 Anti-inflammatory Activity

Liver inflammation is caused by the production of pro-inflammatory cytokines such as TNF- α , IL-1 β , and IL-6 by activated Kupffer cells. These cytokines cause liver damage by inducing cell death through necrosis and apoptosis. The phytochemical constituents of *Clitoria ternatea* have anti-inflammatory properties and they are capable of inhibiting the activity of the pro-inflammatory transcription factor, Nuclear factor-kappa B (NF- κ B). This leads to a decrease in the production of TNF- α IL-1 β , and IL-6. The reduction in pro-inflammatory cytokines reduces liver damage that is brought about by liver inflammation. The decrease in NF- κ B activity also prevents the recruitment of inflammatory cells to the liver. This shows that the anti-inflammatory properties of this plant extract are useful in the management of liver inflammation.

5.3 Hepatoprotective Effect Of *Clitoria Ternatea*

The antioxidant and anti-inflammatory properties of *Clitoria ternatea* contribute towards its hepatoprotective effects. This means that the extract can protect the liver against damage that is caused by various toxic substances. The ability of this plant to reduce hepatic enzymes levels indicates that it is effective in the treatment of liver diseases. The

following section discusses the proposed mechanisms of action of this plant extract in the management of liver inflammation.

5.4 Proposed Mechanisms Of Hepatoprotection By *Clitoria Ternatea*

The hepatoprotective effects of the extract of *Clitoria ternatea* are brought about by a combination of various mechanisms. The antioxidant properties of this plant help in reducing oxidative stress and protecting the liver against damage. The anti-inflammatory properties prevent liver inflammation that may lead to liver fibrosis (Pinzani & Parola, 2018). The inhibition of NF- κ B activity by this plant extract decreases the production of pro-inflammatory cytokines such as TNF- α , IL-1 β , and IL-6. The increased synthesis of antioxidant enzymes such as SOD, CAT, and GSH by this extract also protects the liver from damage (Pinzani & Parola, 2018). Therefore, all the various phytochemical constituents of this plant contribute towards its protective effects on the liver. The synergistic effects of these constituents are responsible for the therapeutic efficacy of this plant extract in the management of liver inflammation. The current review discusses the experimental evidence that shows that this plant extract is effective in the management of liver inflammation. The review will also highlight the current gaps in the research on this plant and provide future perspectives on the development of this drug for the management of liver inflammation.

5.5 Experimental Evidence for the Hepatoprotective Effect of *Clitoria Ternatea*

Various studies have shown that the extract of *Clitoria ternatea* is effective in reducing the levels of hepatic enzymes indicating that it is capable of protecting the liver against damage. For instance, in a study conducted by (Kumar et al., 2020), it was found that treatment with methanolic extract of *Clitoria ternatea* significantly reduced levels of AST, ALT, ALP, and bilirubin in the experimental animals (Nithianantham et al., 2017) methanolic. This indicates that this plant extract is effective in restoring normal liver function in cases of liver damage. The histopathological examination of the experimental animal livers that were treated with this extract also showed a marked decrease in necrosis and fatty degeneration. This shows that the extract helps in the recovery of the liver tissue.

However, most of the studies that have been conducted on this extract have used in-vitro and animal models. More studies need to be carried out to establish the effectiveness and safety profile of this extract in humans.

6. Current limitations and Research Gaps

6.1 Lack of clinical evidence

One of the major limitations was to be the lack of clinical evidence. the studies are carried out *in vivo* (animal experiments) and cell cultures. Positive results in animals cannot always be directed towards humans hence human clinical trials are needed to improve the research. The clinical efficacy and safety is also stated to be uncertain. Therefore, well-designed clinical trials are required before *Clitoria ternatea* can be recommended for routine clinical use in liver disorders. (Mukherjee, 2015)

6.2 Lack of standardization

Each study shows various effects of the extract due to the variety of extracts prepared by each researcher such as methanolic extracts, ethanolic extracts, aqueous extracts using different parts of the plant such as flowers, leaves and roots with different doses and different treatment duration. this part of the research is difficult to compare results as one extraction method may show stronger results than the other (Chandra et al., 2016) (Mukherjee, 2015)

6.3 Bioavailability Challenges

The primary phytoconstituent anthocyanin's have an excellent antioxidative activity however they do have their weakness such as poor absorption, rapid metabolism hence degradation in the stomach and only a limited amount reaches the liver after oral administration. Hence the role of novel drug delivery system plays a main role in the

improvement of bioavailability, stability and absorption through nanoparticles, nanoemulsions, phytosomes and lyposomes.

6.4 Safety

Most of the studies show the report of having low toxicity and good safety profile but the long term studies are missing on chronic toxicity, herb drug interactions and pregnancy safety

6.5 mechanic steps

We need more studies on how the plant works for the specific gene expression, molecular targets, MAPK pathways because every report simply shows us how the ALT, AST, ALP has been decreased and the histology has improved

7. Future perspective

Future studies should focus on overcoming the current limitations and improving the pharmaceutical applications of *Clitoria ternatea* in the management of liver diseases.

7.1 Precised medicine and Standardized herbal medicines

The future treatments may become increasingly personalized on an individuals genetic profile, specific biomarkers and the stage of disease. For the herbal medicines, they must be of consistent quality. The medicines should be developed in capsules, tablets, herbal formulations and with stanstdardized extraction (Sookoian & Pirola, 2021)

7.2 Ai and drug discovery

Artificial intelligence (AI) is rapidly transforming pharmaceutical research and drug discovery. The AI based computer tools can assist in identification of active phytochemicals, Performing molecular docking. AI could be primarily be used to reduce the drug discovery time and to optimize formulations (Vamathevan et al., 2019)

7.3 Advanced drug delivery systems

The *Clitoria ternatea* plant has some good stuff in it that can help people feel better. We can make this stuff work better by using new ways to get it into the body. Things, like particles, special plantbased delivery systems and tiny bags of medicine can help it last longer work better when taken by mouth get to the liver where it is needed and release slowly over time. People who make medicine should keep working on these ideas so we can get the most out of the *Clitoria ternatea* plant and help people get better. (Bonifácio et al., 2014)

8. Conclusion

Liver disease continues to be a major global health burden (Asrani et al., 2019), with hepatic inflammation (Pinzani & Parola, 2018) playing a significant role in the progression of liver injury. Oxidative stress and inflammatory pathways are the major contributors to hepatocellular damage, eventually leading to chronic liver disorders such as fibrosis, cirrhosis, and hepatocellular carcinoma.

Clitoria ternatea is a medicinal plant with considerable therapeutic potential due to its rich phytochemical composition. It contains several bioactive compounds, including anthocyanins, flavonoids, phenolic compounds, and cyclotides, which exhibit antioxidant, anti-inflammatory, and hepatoprotective activities. These phytoconstituents work synergistically to protect liver cells by reducing oxidative stress, suppressing inflammatory responses, and preserving normal liver function.

Current research has demonstrated promising hepatoprotective effects of *Clitoria ternatea* in both in vitro and in vivo studies. Improvements have been reported in liver biomarkers such as ALT, AST, ALP, and bilirubin, along with

restoration of normal liver histology. However, most of the available evidence is based on experimental studies, and human clinical data remain limited.

Future research should focus on conducting well-designed clinical trials to establish the efficacy and safety of *Clitoria ternatea* in humans. Furthermore, the development of standardized herbal formulations and the application of advanced drug delivery systems, such as nanoparticles, nanoemulsions, liposomes, and phytosomes, may improve the bioavailability, stability, and therapeutic effectiveness of its phytoconstituents. (Akbarzadeh et al., 2013)

Overall, *Clitoria ternatea* represents a promising source of hepatoprotective phytoconstituents with significant pharmaceutical potential. Continued research focusing on clinical validation, standardization, and innovative pharmaceutical technologies may facilitate its future development as a safe and effective therapeutic option for the management of hepatic inflammation.

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