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Phytochemicals and Medicinal Uses of *Clitoria ternatea*

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

The plant *Clitoria ternatea*, commonly known as 'Butterfly pea,' has a rich history of traditional use in Ayurvedic medicine, where different parts of the plant are utilized to used health concerns like indigestion, constipation, arthritis, skin diseases, liver, and intestinal problems. Beyond its medicinal uses, the flowers of *C. ternatea* have gained popularity worldwide as ornamental flowers and have been traditionally employed as a natural food colorant. This review paper aims to explore recent advancements in the medicinal uses and study of phytochemicals from *C. ternatea* flowers, focusing on their potential biological activities. By examining these developments, the paper seeks to provide valuable insights into the therapeutic potential and diverse applications of *C. ternatea* flowers, opening new avenues for further research in this promising area of study. of phytochemicals from *C. ternatea* flowers. *Clitoria ternatea* flower is a promising candidate for functional food applications owing to its wide range of pharmacotherapeutic properties as well as its safety and effectiveness.

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1. INTRODUCTION

Since ancient times, aromatic and medicinal plants have been utilized for therapeutic, religious, cosmetic, nutritional, and beautifying purposes, and mankind of all civilizations and cultures is familiar with their use [1,2,3]. *Clitoria ternatea* is a perennial climber (2–3 m in height) and is known by its common name as butterfly pea or blue pea flower [4].

This plant is widely cultivated for its ornamental value and is also utilized as a species for revegetation purposes. In Southeast Asia, the blue pigment from its flowers has a traditional use as a natural food colorant [5,6]. Additionally, it is recognized for its suitability as a cover crop and green manure, possessing the ability to effectively suppress perennial weeds and enrich the soil through nitrogen fixation [7] (Reid and Sinclair, 1980).

Clitoria ternatea is recognized as a nootropic herb in Ayurvedic medicine [8]. It thrives in regions with full sunlight or partial shade, and its seed germination typically takes around 1-2 weeks, with flowering occurring approximately 4 weeks after germination [9,10,11,12]. This plant exhibits several variations with different flower colors, including light blue, dark blue, white, and mauve, each of them measuring 4-5 cm in length (Fig. 1). Compounds reported to be found in the flowers are ternatin anthocyanins and various flavanol glycosides of kaempferol, quercetin and myricetin [4,13,14]. The leaves of *Clitoria ternatea* are pinnate, composed of 5-7 leaflets, and have an elliptic-oblong shape with lengths ranging from 2.5 to 5.0 cm and widths from 2.0 to 3.2 cm. The plant produces flat, linear, and beaked seed pods, which have a length range of 5-7 cm and are edible when tender. The seeds are oval-shaped and have a blackish or yellowish-brown color, with lengths varying from 4.5 to 7.0 mm and widths from 3 to 4 mm. *Clitoria ternatea* has a taproot system with numerous slender lateral roots [15,4].

Fig. 1. *Clitoria ternatea* plant part: a) leaf and vines, b) Flower and c) Pod

Table 1. Names of *Clitoria ternatea* (Butterfly Pea) in different regions and languages

Region	Language	Name
Bengal	Bengali	Aparajita
India	Hindi	Kajroti
Brazil	Brazilian Portuguese	Cunha
Portugal	Portuguese	Cunhã, Fula Criqua
China	Chinese	Lan Hu Die
Indonesia	Indonesian	Bunga Biru, Tembang Telang
Malaysia	Malaysian	Bunga Telang
Spain	Spanish	Clitoria Azul
Thailand	Thai	Dangchan
Vietnam	Vietnamese	Chi Dậu Biếc
Turkey	Turkish	Mavi Kelebek Sarmaşığı

[15,16,4]

2. MORPHOLOGY

The taxonomical classification of *Clitoria ternatea* species

Kingdom	:	Plantae
Division	:	Magnoliophyta
Class	:	Magnoliopsida
Subclass	:	Rosids
Order	:	Fabales
Family	:	Fabaceae
Subfamily	:	Papilionoideae
Genus	:	*Clitoria*
Species	:	*ternatea* (Linnaeus)

Table 2. Nutritional analysis of *C. ternatea* flowers

Nutrient	Percentage	Concentration (mg/g)
Protein	0.32%	-
Fiber	2.1%	-
Carbohydrate	2.2%	-
Fat	2.5%	-
Moisture	92.4%	-
Calcium	-	3.09 mg/g
Magnesium	-	2.23 mg/g
Potassium	-	1.25 mg/g
Zinc	-	0.59 mg/g
Sodium	-	0.14 mg/g
Iron	-	0.14 mg/g

Neda et al., (2013)

Table 3. Bioactive compounds identified in *Clitoria ternatea* flowers

Compound Type	Identified Compounds	References
Anthocyanins	Ternatins A1, A2, B1, B2, D1, D2, and others (15 (poly) acylated delphinidin glucosides)	Mukherjee et al. [4]; Terahara et al. [17]
Flavanols	Kaempferol, Quercetin, and Myricetin glycosides (With variations in substitutions at R1, R2, R3, and R4)	Mukherjee et al. [4]; Kazuma et al. [13,14]
Lipophilic Compounds	Fatty Acids (Palmitic Acid, Stearic Acid, Linoleic Acid, etc.)	Shen et al. [18]

Compound Type	Identified Compounds	References
	Phytosterols (Campesterol, Stigmasterol, β-sitosterol, etc.)	
	Tocols (α-tocopherol and γ-tocopherol)	
Others	Mome Inositol, Pentanal, Cyclohexen, etc.	Neda et al. [19,20]
	6″-Malonylastragalin, Phenylalanine, Coumaroyl Sucrose, etc.	Zakaria et al. [21]
	Tryptophan, Coumaroyl Glucose, etc.	

2.1 Distribution

Clitoria ternatea, commonly known as the *C. ternatea* plant, has a widespread distribution across various regions. It can be found in numerous tropical Asian countries such as India, the Philippines, Bangladesh, Bhutan, Nepal, Sri Lanka, and the Maldives. Additionally, it is also present in regions of South and Central America, the Caribbean, as well as Madagascar. Moreover, the plant is observed in parts of the Middle East, including Saudi Arabia, Yemen, Iran, and Iraq, along with China Taiwan, Indonesia, Malaysia, Singapore, Cambodia, Laos, Myanmar, Thailand, and Vietnam. The wide distribution of *C. ternatea* highlights its adaptability to diverse climatic conditions in these regions [22] (Ambasta, 1988).

2.2 Traditional Uses

Root was used for the treatment of ascetics, enlargement of the abdominal viscera, sore throat and skin diseases. They were also used as purgative, but because, they cause griping and tenderness, they were not recommended. Root was administered with honey and ghee as a general tonic to children for improving mental faculties, muscular strength and complexion tonics. Seeds and leaves were widely used as a brain tonic and to promote memory and intelligence. Juice and flowers were used as an antidote for snake bite. Seeds were used in swollen joints; crushed seeds are taken with cold or boiled water for urinary problems [23,24,25,26].

Fig. 2. Traditional uses of *Clitoria ternatea*

2.3 Plant Parts Used

Leaves, seeds, bark, fruits, sprouts and stems were used medicinal [27,28].

2.4 Chemical Constituents

Butterfly pea (*Clitoria ternatea*) contains a wide range of chemical compounds, each contributing to its therapeutic benefits. The plant's chemical composition includes tannins, phlobatannins, carbohydrates, saponins, triterpenoids, phenols, flavonoids, flavanol glycosides, proteins, alkaloids, anthraquinones, anthocyanins, cardiac glycosides, Stigmast-4-ene-3,6-dione, volatile oils, and steroids. These diverse chemical constituents play a significant role in the medicinal properties of Butterfly pea. Here is a list of the principal chemical components found in this plant [29,30].

2.5 Pharmacological Actions of Butterfly Pea

Butterfly pea includes a variety of chemicals with therapeutic effects. These include alkaloids, flavonoids, and glycosides. Alkaloids are chemicals that can stimulate or depress the central nervous system. Flavonoids are plant chemicals with antioxidant and anti-inflammatory effects. Glycosides are substances that can be broken down into sugar and a non-sugar component. The non-sugar component of Butterfly pea glycosides possesses anti-cancer effects.

2.6 Anticancer Activity

Butterfly pea (*Clitoria ternatea*) is well-known for its potent anticancer effects. *In vitro* studies have shown significant dose-dependent cytotoxic activity of *Clitoria ternatea* extracts. The petroleum ether extract achieved a 100% reduction in cell count at 500 µg/ml, while the ethanolic extract exhibited an 80% reduction at the same concentration. Moreover, the water extract demonstrated significant effects against MCF-7 breast cancer cells, with an IC50 value of 175.35 µg/ml [31].

In vivo experiments using the methanol extract of *Clitoria ternatea* in DLA-bearing mice exhibited promising results. The treatment increased survival time and decreased tumor volume, indicating potential therapeutic benefits against cancer. These findings underscore the potential of *Clitoria ternatea* as a valuable natural source for developing anticancer agents [32].

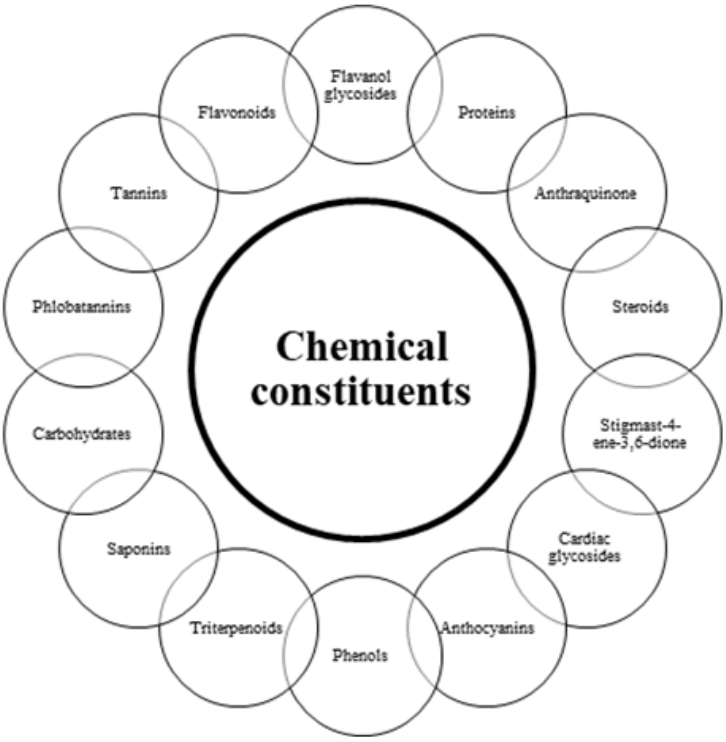

Fig. 3. Chemical constituents of *Clitoria ternatea*

2.7 Antimicrobial Effect

Clitoria ternatea extracts have demonstrated inhibitory effects against a variety of pathogens, including bacteria, fungi, and viruses. The methanol extracts from both the leaf and root exhibited the most potent antimicrobial activity, with MIC (Minimum Inhibitory Concentration) values ranging from 0.3 mg/ml to 100.00 mg/ml against various bacterial, yeast, and fungal species. Among the tested organic solvent extracts (petroleum ether, ethyl acetate, and methanol), the methanol extract proved to be the most effective [33].

2.8 Anti-inflammatory Antipyretic and Analgesic Effects

The ethanol extract of *Clitoria ternatea* root (ECTR) showed antihistaminic activity by inhibiting clonidine-induced catalepsy in mice, but it did not exhibit the same effect against haloperidol-induced catalepsy. In contrast, the methanol extract of *Clitoria ternatea* root with blue flowers (MECTR) demonstrated anti-pyretic potential. It effectively reduced normal body temperature and yeast-induced pyrexia in rats, comparable to the effects of paracetamol [34,35].

2.9 Antiparasitic and Insecticidal Effects

Clitoria ternatea's ethanolic extract (100mg/ml) induced paralysis in Indian earthworms (*Pheretima posthuma*) within 15-20 minutes and led to their death within 28-30 minutes. Among the various extracts, the methanol extract of *Clitoria ternatea* roots exhibited the most potent anthelmintic activity. Both the aqueous and ethanolic extracts of *Clitoria ternatea* leaves demonstrated significant anthelmintic activity against Eisenia foetida, with the ethanolic extract showing higher efficacy. Furthermore, the seed extract of *Clitoria ternatea* displayed promising mosquito larvicidal activity against *Aedes aegypti*, *Culex quinquefasciatus*, and *Anopheles stephensi* [36,37,38].

2.10 Antioxidant Activity

Clitoria ternatea flower petal extract (CTE) demonstrated potent antioxidant activity and protected erythrocytes against oxidative damage. *Clitoria ternatea* leaf extracts showed significant antioxidant effects and reduced DNA damage. Aqueous extracts exhibited stronger antioxidant activity compared to ethanol extracts. Methanolic extract of *Clitoria ternatea* leaf showed antioxidant properties and a hepatoprotective effect in mice against paracetamol-induced liver toxicity [39,40].

2.11 Neuroprotective Activity

Clitoria ternatea has been found to have neuroprotective qualities, which may be linked to its antioxidant and anti-inflammatory capabilities. It has showed promise in preventing neurodegenerative disorders and increasing cognitive function.

2.12 Anthelmintic Activity

The ethanolic extract of *Clitoria ternatea* (CT) leaves exhibited anthelmintic activity at 100 mg/ml. However, in another study, anthelmintic activity was observed with the methanolic extract of CT leaves at 10 mg/ml and 25 mg/ml, while no such activity was found with the ethanolic extract at the same concentrations.

2.13 Medicinal Properties

Butterfly pea has a wide range of medicinal applications due to its diverse pharmacological properties. Here are some of the notable medicinal applications of Butterfly pea.

2.14 Diuretic and Anti-urolithiasis Effect

The alcoholic extract derived from *Clitoria ternatea* leaves exhibited robust inhibitory potency against the formation of calcium oxalate crystals, which is comparable to the effect of the proprietary drug Cystone used for dissolving kidney stones. Notably, the extract showed a higher percentage of inhibition of calcium oxalate crystallization in vitro compared to Cystone.

2.15 Central Nervous Effect

Clitoria ternatea extracts have shown promising memory-enhancing and cognitive effects, including significant anxiolytic, antidepressant, and CNS-depressant activities. The extracts increased acetylcholine content in the hippocampus, leading to improved learning and memory. Additionally, they enhanced passive avoidance learning and retention by increasing dendritic intersections and branching in

amygdaloid neurons. The extracts also exhibited anti-amnesic effects, boosted acetylcholine content, and increased acetylcholinesterase activity in the brain. Overall, *Clitoria ternatea* extracts demonstrated nootropic, anxiolytic, antidepressant, anticonvulsant, and antistress activities, making them promising candidates for cognitive enhancement and neuroprotective interventions.

2.16 Diabetes Control

Clitoria ternatea extracts exhibited noteworthy antidiabetic effects in diabetic rats. Methanol, water, petroleum ether, and chloroform extracts were able to reduce blood glucose levels. The aqueous extracts of leaves and flowers showed improvements in glucose and insulin levels while reducing enzyme activity. The alcoholic root extract demonstrated preventive effects against diabetic complications in the brain and pancreas. Moreover, *Clitoria ternatea* extract showed inhibition of advanced glycation end product (AGE) formation and displayed strong antioxidant properties, indicating its potential as a therapeutic intervention for diabetic complications.

2.17 Wound Healing Effect

Clitoria ternatea seed and root extracts have demonstrated remarkable wound healing activity in various models, including excision, incision, and dead-space models, whether administered orally or applied topically. These extracts exerted their effects on all phases of wound healing: the inflammatory, proliferative, and remodeling phases. Moreover, the standardized leaf extract exhibited inhibitory activity against enzymes involved in skin wound healing, such as hyaluronidase and matrix metalloproteinase-1 (MMP-1). The presence of the bioactive compound taraxerol in the extract and ethyl acetate fraction is believed to contribute to its wound healing potential. Overall, *Clitoria ternatea* extracts hold promise as natural agents for promoting effective wound healing [41-45].

3. CONCLUSION

In conclusion, *Clitoria ternatea*, commonly known as Butterfly pea, holds immense medicinal potential and has been utilized since ancient times for various therapeutic purposes. Its traditional use in Ayurvedic medicine for treating health concerns such as indigestion, arthritis, and skin diseases has been well-documented. Furthermore, the flowers of *C. ternatea* have gained global popularity as ornamental flowers and natural food colorants. The plant has demonstrated significant effects in wound healing, memory enhancement, antidiabetic activity, and antimicrobial properties. Additionally, its antioxidant, neuroprotective, and anthelmintic activities have been well-documented. The various bioactive compounds identified in *C. ternatea*, such as anthocyanins, flavonols, and lipophilic compounds, contribute to its therapeutic benefits and add to its value as a natural remedy. Moreover, its adaptability to different climates and wide distribution across various regions make it a promising candidate for functional food applications. The micropropagation techniques discussed in this review offer valuable tools for mass-producing homogeneous and disease-free plantlets, contributing to the conservation and commercial production of *Clitoria ternatea*.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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