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Clitoria ternatea (Blue Tea): A Comprehensive Review of Its Phytochemistry, Pharmacology, and Toxicology

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KEYWORD

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Clitoria ternatea Linn,

Antimicrobial,

Antidepressant,

Anti-carcinogenic,

Potential activity,

Toxicology

ABSTRACT:

Introduction/Objective: *Clitoria ternatea* L. (Blue Tea), is a traditional Ayurvedic medicinal plant recognized for its cognitive-enhancing, anxiolytic, antidepressant, anticonvulsant, anti-inflammatory, and antioxidant properties. It contains diverse secondary metabolites including flavonol glycosides, triterpenoids, anthocyanins, and steroids. This review aims to collectively present updated evidence on its phytochemical profile, pharmacological actions, and therapeutic potential, highlighting the link between traditional use and modern science.

Methods: A structured literature review was conducted using published articles from scientific databases, focusing on phytochemistry, pharmacological activities, and reported therapeutic benefits. Experimental and preclinical studies were primarily considered to evaluate biological activities.

Results: *Clitoria ternatea* extracts demonstrated significant enhancement of cholinergic neurotransmission, improving learning and memory while reducing anxiety. Antioxidant activity contributed to reduced oxidative stress, potentially preventing chronic disease onset. Extracts also exhibited anti-diabetic, lipid-regulating, antimicrobial, larvicidal, anticancer, and neuroprotective effects. Consumption in the form of blue tea has shown growing acceptability in the Indian market due to health benefits and affordability.

Discussion: Findings support the medicinal relevance of *Clitoria ternatea*; however, variations in extraction methods and limited human clinical studies restrict confirmation of efficacy and safety. Standardization of preparation and dose optimization remain necessary for therapeutic application.

Conclusion: *Clitoria ternatea* represents a promising multipurpose medicinal plant with diverse pharmacological activities. Future research should emphasize clinical evaluations, toxicity profiling, and drug-interaction assessments to facilitate its development into validated natural therapeutic agents.

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1. Introduction

Clitoria ternatea (Blue tea or Butterfly pea) originated in tropical Asia and disseminated extensively over Latin and South America the Eastern West Indies China and India where it has grown established. It has elliptic, obtuse leaflets and is a perennial herbaceous plant [2]. Large solitary, axillary, papilionaceous blooms are produced by the shrub. Variability in flower color and petals has been documented in this species [3]. Mainly the species is found in Latin and South America, but nowadays it is cultivated in the warmer part of the world, including India [1]. In previous times, the bufferfly peas were cultivated for the show purpose later it is used for the cattle feed because of its high protein [4]. It is a medium-high plant with a high quality therapeutic benefit [5]. kaempferol and related glycosides, aparajitin, anthocyanins, γ-sitosterol and related sterols, hexacosanol, β-sitosterol, and anthoxanthins have all been found in *Clitoria ternatea* [7]. Tripsin inhibitor (Vatexin and isovatexin polyphenols, phytic acid and tannic acid) and aromatic component hexanol, benzoyl alcohol, methyl 2-propanal and pentanol are also present [8]. Because of high protein it lowers the risk off of atherosclerosis [6]. *Clitoria ternatea* falls under legumes which is having a very high protein especially dietary protein. *Clitoria ternatea* are shown to be antihyperlipidemic activity in a model of diet-induced hyperlipidemia and acute hyperlipidemia caused by poloxamer [9]. Tease refreshing flavor , alluring Scent possible health benefit are some of the factors that make tea the second most popular beverage in the world after water. The consumption of herbal teas nowadays is increasing because of the health-hazardous effects of caffeinated beverages like tea and coffee [10]. Blue tea, often called butterfly pea flower tea is a caffeine-free herb infusion made from dried or fresh clitoria ternetea plain leaves. Herbal tea created from flowers includes chamomile and Blue pea [11]. The blue tea is having zero caffine and lots of antioxidant. It is excellent supplement for the redox diet and it remove the ROS in the body [11]. As a natural diuretic blue tea is set to aid in the loss of water weight [1]. Although this is not clinically proven but suggest that Gluti can help manage diabetes , it is said to help regulate blood sugar level . The tea is also said to manage the strangely living qualities and may help reduce anxiety symptoms [9].

Wide range of pharmacological activities has been reported for *Clitoria ternatea* Linn., including anti-inflammatory and antioxidant, antibacterial, antidiabetic, and anticarcinogenic properties [1-11]. However, despite the abundance of experimental research, there remains a noticeable absence of a comprehensive, well-structured review that consolidates these findings. This gap highlights the importance and relevance of the present work. The objective of this review is to systematically compile and critically analyze the available scientific data on *Clitoria ternatea*, encompassing its phytochemical profile, pharmacological activities, and therapeutic applications. The information presented herein aims to connect traditional knowledge with modern scientific understanding, thereby bridging the perspectives of Ayurvedic and folk medicine with current pharmacological evidence. This review also seeks to outline the traditional and ethnomedicinal uses of the plant, discuss the classification and biosynthesis of its major phytochemicals, and specify the distribution of these compounds across different plant parts. Furthermore, the work summarizes and compares various extraction and isolation techniques employed in previous studies. By consolidating this information, the review intends to highlight research gaps and propose potential directions for future exploration, including advanced pharmacological and clinical investigations.

1.1. History

"Shankhpushpi" has a long history and is considered a respected Ayurvedic medication with laxative, nervine, and brain tonic properties [12].

According to Ayurvedic scriptures, it is a MEDHYA-RASAYANA [32]. *Conscora decusata, Evolvulus pluricaulis, Clitoria ternatea*, and Convolvulus pluricaulis make up the complete plant [15]. This herb from Ayurveda is used to treat the central nervous system (CNS), particularly to increase intelligence and memory.

Due to its conch-shell-like blossoms, the plant *Clitoria ternatea* is also known as "SHANKPUSHPI" in Sanskrit [13]. It is said to be an effective "MEDHYA" medication and is thus used to cure "Masasika Roga"[14]. This plant's extracts have been used into the rejuvenating formula MEDHYA-RASAYANA, which is used to treat neurological conditions.

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1.2. Taxonomy of *Clitoria ternatea*

Clitoria ternatea (Butterfly pea), a member of the faboideae subfamily of the fabaceae family of legumes. The detailed taxonomical classification, *Clitoria ternatea* is depicted in **Table 1** [16-19].

Table 1. Taxonomy of *Clitoria ternatea*

Kingdom	Plantae
Phylum	Magnoliophyta
Class	Magnoliopsida
Subclass	Rosidae
Order	Fabales
Family	Fabaceae
Genus	Clitoria
Species	Ternatea
Scientific Name	*Clitoria ternatea L.*

1.3. Morphology of Clitoria ternatea

Description of different plant part with the respective figure has been depicted in **Table 2.**

1.4. Traditional use of *Clitoria ternatea*

Clitoria ternatea L., known as butterfly pea or aparajita, is a well-known Ayurvedic medicinal herb. The plant's roots, seeds, leafets, blossoms, shoots are among the components that have been used for generations in traditional medicine. It is categorized as a "Medhya Rasayana" in Ayurveda, signifying its function in improving memory and intelligence. It is traditionaly utilized as a tonic for brain that is said to enhance mental clarity, memory, learning [36, 37, 19].

The roots and seeds are also used as laxatives, nerve tonics, and to manage neurological problems including epilepsy, insanity [39, 40]. Roots are applied to conditions including fever, bronchitis, arthritis, and skin disorders. They are also said to have purgative, laxative, and diuretic qualities [6]. The white-flowered type is preferred over the blue one and is said to have more therapeutic qualities. While powdered roots and decoctions are used to cure rheumatism and ear diseases, root juice is also used topically to treat hemicrania, a kind of migraine [41].

The plant is combined with honey and ghee to improve children's skin, physical strength, and cerebral abilities [17]. The seeds have long been used to alleviate joint swelling, dropsy, and colic [12]. Decoctions of the root and flower are used to cure intestinal and liver problems and to control menstruation in Cuba and other American countries [32]. In addition to its neurological properties, *Clitoria ternatea* is used to treat urinogenital infections, as an anthelmintic, and an insect stings [15]. In Southeast Asia, its delicate portions and colorful blooms are frequently utilized in cooking and as food coloring [13]. Overall, its traditional applications are in the fields of medicine and nutrition, with a focus on its rejuvenating and neuroprotective properties.

A natural source of blue color: at present, the use of food color is extensively increasing to make the food more attractive and more pleasant [14]. There are several food colors available in the market, for example, Brilliant blue, Indigo carmine, etc, but they are all artificial and have some bad health effects [1]. Natural color anthocyanins, carotenoids are natural pigments which are having vibrant colors and are very good for health [1].

But in the current scenario, the blue pigment is difficult to obtain Presently available natural blue sources include genipin-derived pigments and spirulina (phycocyanin), both of which have stability and extraction issues [34]. Anthocyanins are available in many fruits and flowers the color of the anthocyanins is depending on the temperature, humidity and pH of the environment. They have antioxidant, antibacterial, and other health benefits [1].

Butterfly pea contains polyacylated anthocyanins called ternatins. Because of it the vivid blue color we observed in *Clitoria ternatae* [14, 1].

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Table 2: Different plant part of *Clitoria ternatea*

Plant Part	Description	Figure of different parts of the plant	Reference
Leaves	Comprises 5-7 leaflets arranged alternately on pinnate leaves. The length of leaflets approx. 2.5-5 cm as well as 1.5-3.5 cm in wider section, elliptic to ovate, thinly papery, membrane-like. Leaf blades are 1.5-4.7 × 1-3.6 cm, with linear trichomes on both sides. Base rounded, apex retuse; upper (adaxial) surface green, lower (abaxial) surface paler. Linear stipules are 0.2-0.3 cm long, spear-like stipule at each stem node (02.-0.4 × 0.1 cm).		[9, 11, 26]
Root	Roots are Bitter or acidic taste. Root nodules are 0.5-1.5 cm in diameter with 0.05-0.1 cm cortex thickness. Large nodules are sparse; smaller ones are dense which contains leghemoglobin (oxygen carrier that protects the nitrogenase enzyme).		[10, 26]
Seeds	Seeds are dark brown to black in colour. The size of seeds are 4.5-7 mm in lenght, 3-4 mm wide. Seeds contain chemicals like stearic acid, palmitic acid, oleic acid, linoleic acid, linolenic acid, mucilage, delphinidin 3,3,5-triglucoside. Seeds are used for both internal and external medicinal purposes like cough, hepatic disorder, spleen, rheumatic infections.		[24, 26]
Flower	Flowers are white, pink, light/dark blue in colour; funnel-shaped (4 × 3 cm); single or paired. Petals size varies like obovate, notched/rounded apex, blue with yellow base or all white. The anthocyanins (delphinidins) present is mainly responsible for the colour of the plant.		[9, 11, 25, 26]
Stem	Stems are generally thin, twining vine with soft hairs (pubescence), 0.5-3 m long. The dried stems are 15-20 cm in height, 5-10 mm width and the shape is Terete (round), thickness 1-2 mm, which becomes woody with age.		[9, 26]

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2. METHODOLOGY

Various scientific database servey was carried out across multiple scientific databases, including Google Scholar, Medline, PubMed, Scopus, SciFinder, and Sciencedirect. Pharmacological action, phytochemical ingrediants, and ethnomedical usage were the topics of the literature search quaries. The terms "*Clitoria ternatea*," "Butterfly pea," "Phytochemicals" "Traditional uses," "Pharmacological activity," "Toxicology", and "Biological activity" were used to search all databases. High quality papers from 1990 to April 2026 were gathered for this study, which adheres to the recommendation of the reported items for the systematic review.

2.1. Phytochemical screening

Plant parts said to have been used since ancient times include roots, seeds, and leaves. The primary phytoconstituents of *Clitoria ternatea* are two pentacyclic triterpenoids, taraxerol and taraxerone. Alkaloids, flavonoids, saponins, Ternatins, tannins, carbohydrates, proteins, starch, resins, taraxerol, and taraxerone are found in the roots according to phytochemical screening [24]. The detection of taraxerol in *Clitoria ternatea* Linn. has been made easier with the development of a novel High Performance Thin Layer Chromatography technique that is straightforward, sensitive, selective, and accurate [25]. The analysis was carried out using aluminum Thin Layer Chromatography plates [26]. A variety of secondary metabolites have been identified From *Clitoria ternatea* Linn. including as anthocyanins, flavonol glycosides, triterpenoids, and steroids [16]. Four kaempferol glycosides, I, II, III, and IV, were extracted from *Clitoria ternatea* L. leaves [17]. Kaempferol-3-glucoside (I), kaempferol-3-rutinoside (II), and kaempferol-3-neohesperidoside (III) were identified using Protein Magnetic Resonance, Mass Spectrometry, and Ultra Violet [51]. Based on spectral data, clitorin was identified as C33H40O19Kaempferol-3-o-rhamnosyl glucoside [19]. From the different parts of the *Clitoria ternatea* we got different phytochemicals. We found different types of metabolites, like alkaloids, ternatins, saponins, taraxerone, anthocyanins [39], which are depicted in **Figure 1**.

Root: The root of *Clitoria ternatea* contains various types of phytochemicals; it contains alkaloids, tannins, proteins, taraxerol, taraxerone, ternatins, saponins, resins, and starch [40]. The studies showed that the root nodules contain alanine, gamma-aminobutyric acid, glutamic acid, histidine, leucine, and ornithine [12]. In the root's bark, there is generally the presence of starch, resins, flavonol glycosides, and tannins. Steroids, flavonoids, coumarin resins, and alkaloids are derived from the aqueous root extract of *Clitoria ternatea* [32]. Reported by Almeida and co-workers. The ethanolic extract of the root of *Clitoria ternatea* made using the Soxhlet extraction method contained alkaloids, tannins, flavonoids, phenolics, and glycosides [15]. The ethanolic extract of the root of *Clitoria ternatea* has shown presence of phytochemicals; they are alkaloids, proteins, carbohydrates, flavonoids, tannins, triterpenoids, and steroids [13]. Numerous researches looked into and determined the various biologically active components found in *Clitoria ternatea* roots [14].

Seeds: The seed contains various types of metabolites. A study showed the presence of flavonol-3-glycosides, p-hydroxycinnamic acid, 3,5,7,4'-tetrahydroxyflavone, β-sitosterol, ethyl-α-D-galactopyranoside, and γ-sitosterol as anthoxanthin [1]. Water-soluble mucilage, three unknown trypsin inhibitors, delphinidin 3,3,5-triglucoside, a food colouring agent. Saponins, carbohydrates, sterols, flavonoids, phenolic compounds, glycosides, and alkaloids are obtained from the seeds of *Clitoria ternatea* [2].

Leaves: In an experiment, *Clitoria ternatea* blue-flowered leaves contained phenols, glycosides, alkaloids, gum, coumarins, flavonoids, mucilage, quinines, and alkaloids [3]; in another experiment, from white-flowered leaves, here, generally obtained the presence of mucilage, quinines, gum, glycosides, catechol, and alkaloids [4]. The leaves contain numorous secondary metabolites like, terpenoids, flavonoids, alkaloids, coumarins, quinines, glycosides, catechol's, and proteins [5]. Additionally, existence of antioxidant substances such kaempferol-3-monoglucoside, kaempferol-3-rutinoside, β-sitosterol, 3-O-rhamnosyl-(1,6)-glucoside, 3-O-rhamnosyl-(1,6)-neohesperiodoside, 3-O-rhamnosyl-(1,6)-galactoside and 3-O-rhamlnosyl-kaempferol (1,2) O-[rhamnosyl-(1,6)]-O-chalmnosyl-(1,2)-O—glucoside. The methanol extract of the leaf of *Clitoria ternatea* has shown the presence of saponins,

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terpenes, glycosides, and tannins and a small amount of phenols, terpenoids, and alkaloids reported [24].

Flowers: One of the most significant parts of *Clitoria ternatea* is its blooms, which are packed with beneficial phytoconstituents [25]. From different colours of petal obtained some flavonoids as phytoconstituents; Both delphinidin 3-O-(6"-O-malonyl) and delphinidin 3-O-(2"-O-α-rhamnosyl-6"-O-malonyl)-β-glucosideDelphinidin 3-neohesperidoside, delphinidin 3-O-glucoside, and α-glucoside; three flavonol glycosides, and other anthocyanins, flavonols, and ternatins are obtained [26]. The study found that 15 (poly)acylated delphinidin glucosides, including ternatins A1, A3, B1, B2, C1, C2, D1, and D3, were present in all blue flower lines [16]. Instead of a change in the structure of an anthocyanidin from delphinidin, researchers revealed that the blue to mauve flower color shift arises from a lack of (poly)acylated substitutions of glucosyl groups at ternatins' 3′ and 5′ locations [17]. The presence of molecules such as 6″-malonylastragalin, phenylalanine, coumaroyl sucrose, tryptophan, and coumaroyl glucose in addition to anthocyanins and flavonol glycosides [51]. It is identified that the presence of phytosterols like campesterol, stigmasterol, β-sitosterol, and sitostanol; fatty acids like palmitic acid, stearic acid, petroselinic acid, linoleic acid, arachidic acid, behenic acid, and phytanic acid; and tocols like α-tocopherol and β-tocopherol [19]. The overall concentration of certain components from the ethanolic flower extract of *Clitoria ternatea*, such as phenolics, flavonoids, and anthocyanins [39]. The investigation found many significant chemicals, including kaempferol-3-O-(2-rhamnosyl) rutinoside, quercetin-3-rutinoside, delphinidine-3-glucoside, syringentin-3-O-glucoside, and preternatin A3 [40]. Using ethanol as the extraction solvent, research found that the maximum anthocyanin production occurred at 46 minutes and 60.6°C [12].

So, the overall phytoconstituents have numerous pharmacological benefits, including antioxidant, anti-diabetic, antibacterial, larvicidal, antipyretic, hepatoprotective, and anticytotoxic properties and other pharmacological effects [46-65].

Some of the phytochemicals are which are present in *Clitoria ternatea* are described below and phytochemical present in different parts of the plants are listed in **Table 3.**

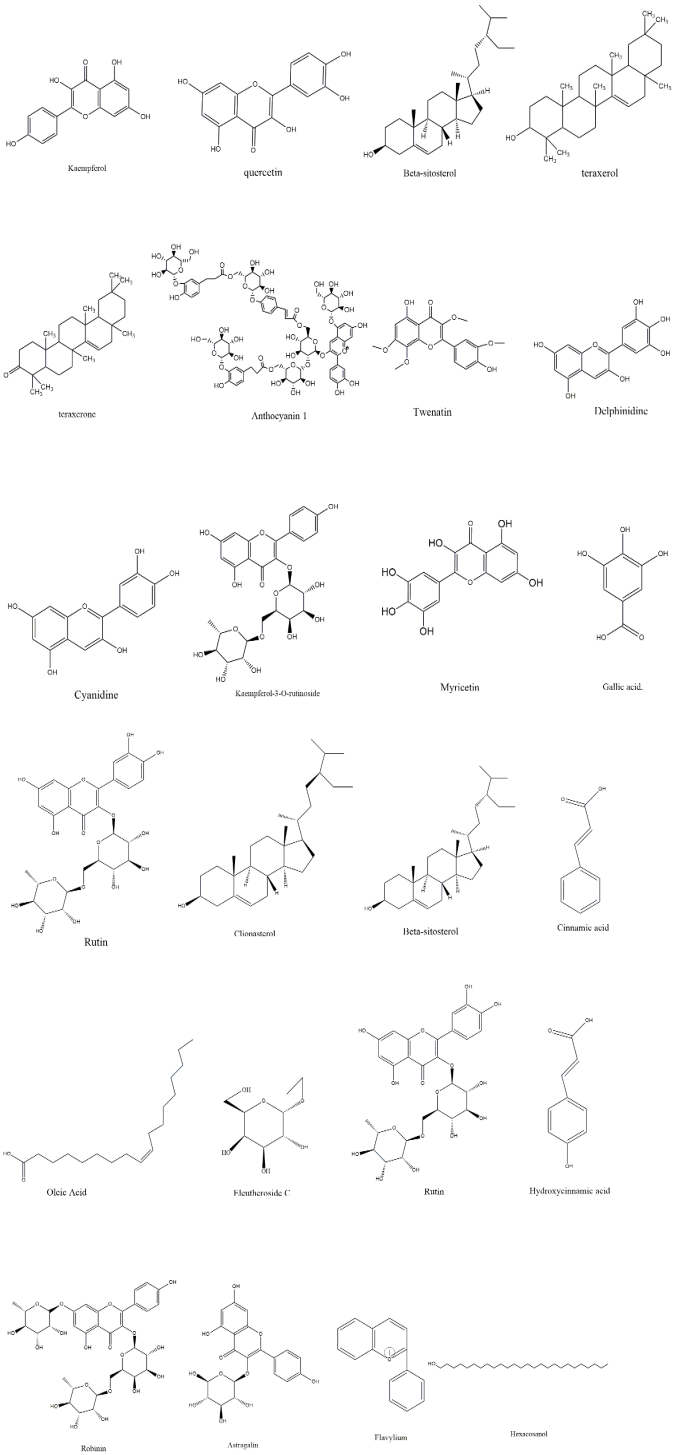

Figure 1: Different phytoconstituents of *Clitoria ternetea*

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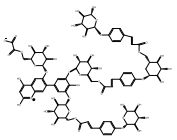
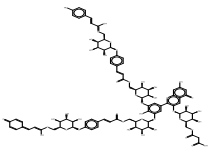
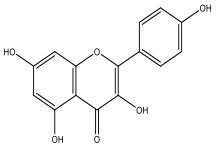
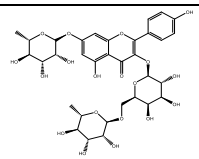
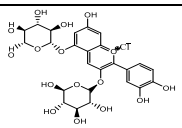
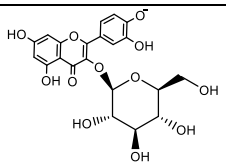
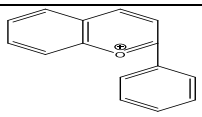
Table 3: List of phytochemicals present in different parts of the plant

Sl. No	Plant Parts	Phytochemicals	Compound Type	Structure	References
1.	Flower	Ternatin A2	Flavonoids		[122, 123]
2.	Flower	Ternatin D1	Flavonoids		[122, 123]
3.	Flower	Kaempferol	Flavonoids		[124, 125]
4.	Flower	Robinin	Alkaloids		[124]
5.	Flower	Cyanin Chloride	Flavonoids		[124]
6.	Flower	Quercetin-3-Glucoside	Flavonoids		[124, 125]
7.	Flower	Flavylium	Polyphenolic		[126]

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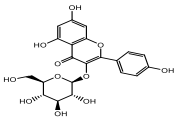
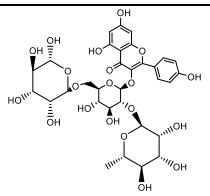
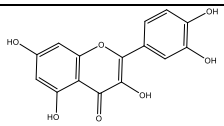
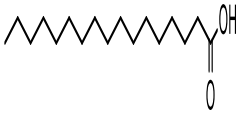
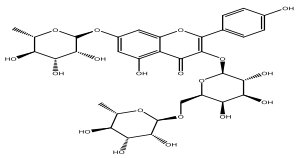
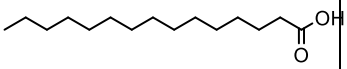
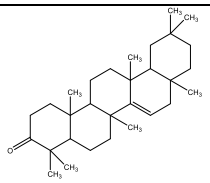
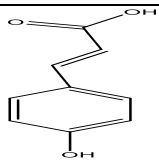
8.	Flower	Astragalin	Glycosylated Flavonoid		[124, 128]
9.	Leaf	Clitorin	Flavonoid		[128, 130]
10.	Leaf	Quercetin	Flavonoid		[125]
11.	Leaf	Stearic Acid	Fatty Acid		[5],[13],[15]
12.	Leaf	Robinin	Flavonoid Glycoside		[128]
13.	Leaf	1-Hexacosanol	Fatty Alcohol		[128]
14.	Leaf	Palmitic Acid	Fatty Acids		[128]
15.	Leaf	Taraxerone	Terpenoid		[127]
16.	Leaf	4-Hydroxycinnamic acid	Polyphenols		[130]

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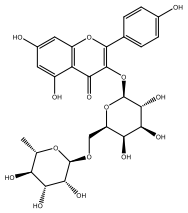
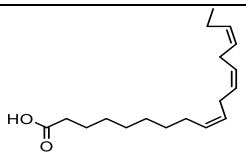
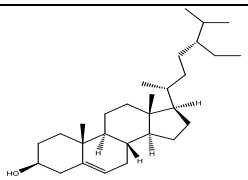
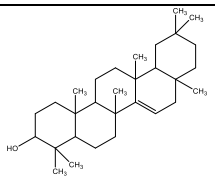
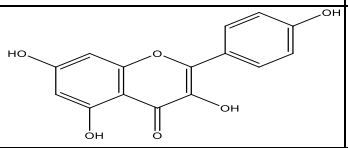
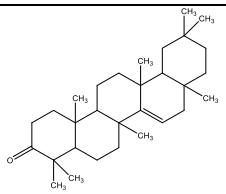
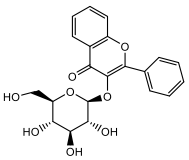
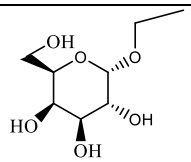
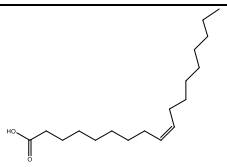
17.	Leaf	Nicotiflorin	Flavonoid Glycoside		[128]
18.	Leaf	Linolenic Acid	Fatty Acid		[128, 131]
19.	Leaf	Beta-Sitosterol	Steroid		[131]
20.	Root	Taraxerol	Terpenoid		[127]
21.	Root	Kaempferol	Flavonoid		[127]
22.	Root	Taraxerone	Terpenoid		[127]
23.	Seed	Flavonol 3-0-D-Glucoside	Flavonoid Glycoside		[128]
24.	Seed	Eleutheroside C	Glycoside		[128]
25.	Seed	Oleic Acid	Fatty Acid		[5]

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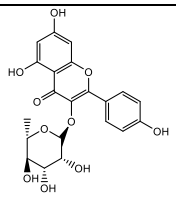
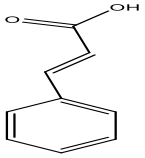
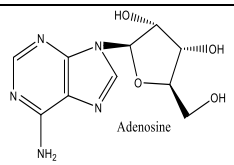
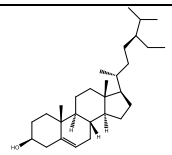
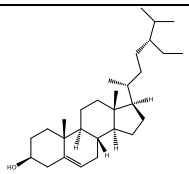
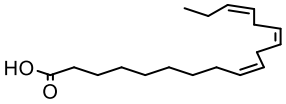
26.	Seed	Afzelin	Glycoside		[128]
27.	Seed	Cinnamic Acid	Glycoside		[128]
28.	Seed	Adenosine	Glycoside		[128]
29.	Seed	Clionasterol	Steroid		[128]
30.	Seed	Beta-Sitosterol	Steroid		[128]
31.	Seed	Linolenic Acid	Omega-3-Fatty Acid		[128, 131]

2.2. Extraction of phytochemicals from *Clitoria ternatea*

Several plant sections, solvents, and extraction methods have been used to extract phytochemicals from *Clitoria ternatea* in order to produce a variety of bioactive substances. The most researched component is the flower, where extraction techniques including Soxhlet, maceration, and ultrasonic-assisted procedures have been used extensively. Different categories of chemicals, including as phenolics, flavonoids, anthocyanins, tannins, terpenoids, steroids, and alkaloids, are produced depending on the solvent—water, ethanol, methanol, or their combinations. Polyphenols and anthocyanins are frequently obtained using aqueous extractions, whereas anthocyanins, such as ternatin derivatives and delphinidin compounds, are best recovered using organic solvents like ethanol and methanol. Depending on the solvent system, leaves and roots can produce substances such saponins, glycosides, resins, coumarins, and taraxerol, making them significant sources of phytochemicals. The yield and kind of phytochemicals are significantly influenced by the extraction method and solvent used; therefore careful selection is crucial for the targeted recovery of bioactive compounds from *Clitoria ternatea*. The techniques of extraction of various phytochemicals listed below in **Table 4.**

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Table 4: Extraction techniques of phytochemicals from *Clitoria ternatea*.

	Plant Part	Extraction Method	Extraction Solvent	Phytochemicals Reported	References
1.	Flowers	Maceration	Water	Phenolics, flavonoids, anthocyanins	[21]
2.	Flowers	Ultrasonic	Water	Phenolics and flavonoids	[20]
3.	Flowers	Maceration	70% ethanol:30% water	Anthocyanins	[132]
4.	Flowers	Ultrasonic	50% ethanol:50% water	Phenolics	[22]
5.	Flowers	Maceration	40% ethanol:60% water	Flavonoids	[23]
6.	Flowers	Maceration	Methanol	Anthocyanins (Ternatin and delphinidin derivatives), kaempferol	[27]
7.	Flowers	Maceration	Methanol:Chloroform	dl-Glyceraldehyde dimer, 1,2-Dioxolan-3-one, 5-ethyl-5-methyl-4-methylene	[23]
8.	Flowers	Maceration	Dichloromethane: cyclohexane: ethyl acetate (2:3:0.5)	Phenols, flavonoids, tannins, alkaloids, terpenoids, cardiac glycosides, steroids	[27]
9.	Leaves	Maceration	50% methanol:50% water	Tannins, saponins, flavonoids, alkaloids, glycosides, phenols	[27]
10.	Leaves	Maceration	Acetone	Carbohydrate, terpenoids, alkaloids, tannin, saponin, phenols	[94]
11.	Leaves	Maceration	Water	Carbohydrate, alkaloids, tannin, saponin, phenols, flavonoid	[94]
12.	Leaves	Maceration	60% methanol:40% water	Alkaloids, flavonoid, resins, tannin, saponin, steroid, phenol, glycosides	[95]
13.	Leaves	Soxhlet	70% ethanol:30% water	Alkaloids, flavonoids, glycosides, tannins, steroids	[96]
14.	Roots	Soxhlet	Ethanol	Phenolic, flavonoids, alkaloids, glycosides, tannins	[96]
15.	Roots	Maceration	Water	Carbohydrate, terpenoids, alkaloids, steroids, phenol	[94]
16.	Roots	Maceration	Acetone	Carbohydrate, terpenoids, alkaloids, saponin, phenol	[94]
17.	Roots	Maceration	Chloroform:Methanol (15:1)	Alkaloids	[99]
18.	Roots	Maceration	Hexane:ethyl acetate (80:20)	Taraxerol	[133]
19.	Roots	Maceration	Toluene:ethyl acetate (7:1)	Alkaloids, flavonoids, steroid, carbohydrates, coumarins, resin	[129]
20.	Flowers	Ethanol	Ethanol	Anthocyanins	[129]
21.	Flowers	Methanol	Methanol	Anthocyanins (Ternatin A1, A2, B1, B2, C1, D1, D2), delphinidin derivatives, kaempferol	[96]
22.	Flowers	Water	Water	Anthocyanins	[133]
23.	Flowers	Ethyl acetate and hexane (1:1)	Ethyl acetate and hexane	Fatty acids, sterols, tocopherols	[95]

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24.	Flowers	Maceration	40-50% ethanol	Anthocyanins	[94]
25.	Flowers	Water	Water	Extract yield (Polyphenols)	[27]
26.	Flowers	Maceration with ethanol	40% ethanol	Phenolics	[27, 133]

3. PHARMACOLOGICAL ACTIVITY

3.1. Neurological / CNS-related Activities

3.1.1. Anti-epileptic activity

To screen extract of methanol from the aerial portions of *Clitoria ternatea*, mice were given 0.1 g/kg p.o. of Pentetrazol (PTZ) and maximal electroshock (MES) to elicit convulsions. *Clitoria ternatea* significantly delayed the onset of convulsions and the duration of the tonic hind limb extension in convulsions brought on by MES [66-70].

3.1.2. Phenobarbitone-induced sleeping time

Rats were used to evaluate potentiation of the phenobarbitone-induced sleep duration in order to examine the inhibition of the HMG-CoA reductase enzyme in the liver (Walker & Parry, 1949). Six animals were placed in each of the many groups that were created [14]. One was given to the control group intraperitoneal dose of phenobarbitone (80 mg/kg) [71, 72]. One hour before to the phenobarbitone injection, each test extract was administered to the treatment groups at dose of 0.5 g/kg, p.o. The righting response of the animals was noted [71, 72]. When an animal is placed on one side and does not return to its regular posture within 30 seconds, it is said to have lost its righting reflex [13].

3.1.3. Nootropic activity and Anxiolytic activities

The Elevated Plus Maze test (EPM) and Object Recognition Test (ORT) were used to assess the effects of extracts from the aerial portions of *Clitoria ternatea* on memory and anxiety [73, 74]. Mice given 100 mg/kg extract performed better in terms of memory, spending more time investigating novel items and exhibiting lower transfer latency, which suggests enhanced learning and recall without compromising long-term memory [73, 74, 77].

In the EPM and light/ dark experiments, the methanolic extract also shown slight anxiolytic (anti-anxiety) effects. While lower dosages (30mg/kg) showed no impact, treated animals spent extra time in the dark box and open arms at doses of 0.1-0.4 g/kg, indicating decreased anxiety levels [74, 75, 76].

3.1.4. Antidepressant, Tranquilizing and Sedative activity

Scientists assessed, using the tail suspension test, the effectiveness of a extract of methanol *Clitoria ternatea*'s aerial component as an antidepressant at doses of 0.1 and 0.4 g/kg. The amount of time a patient was immobile was greatly decreased by oral delivery of *Clitoria ternatea*. *Clitoria ternatea* lowered the overall amount of time that a patient was immobile, enhanced cognitive function, it did not result in behavioral toxicity or sedation [78, 81].

Researchers looked into how *Clitoria ternatea* affected cognitive ability, anxiety, sadness, stress, and convulsions brought on by PTZ and MES [78, 80]. The extract showed nootropic action in the elevated plus maze (EPM) by increasing the discriminating index in the object identification test and decreasing the transfer latency (TL), or the amount of time required to take up the middle platform [83]. The tail suspension test, it decreases the time period of immobility, decreased the convulsive effects of PTZ and MES, and decreased stress-induced ulcers [78, 80]. The extract tended to lessen the severity of behavior mediated by AcH and serotonin [14]. Behavior mediated by dopamine and noradrenalin was not affected in any noticeable way [79, 84]. In short, the extract was shown to have nootropic, antidepressant, anxiolytic, and anti-stress qualities [111, 79, 80, 83]. Nootropic drugs enhance cognitive function, memory, and learning [82].

3.2. Antimicrobial / Anti-parasitic Activities

3.2.1. Antimicrobial effect

The antimicrobial efficiency of plant extracts is often solvent dependent for instance, methanolic extracts of

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various other plants (e.g. *Agaricus bisporous*) showed pronounced antibacterial activity whereas aqueous extracts were less effective this aligns with observation in *Clitoria ternate* where organic solvent extracts tend to yield higher antimicrobial potency [137]. Strong antibacterial activity was proved by *Clitoria ternatea* extract against various microbial entities mostly fungi and bacteria. The acetone extract was most effective against *Klebsiella pneumoniae* (17 mm) and *Streptococcus agalactiae* (19 mm) but the ethanolic extract demonstrated the greatest suppression against *A. formicans* (18 mm) *A. hydrophila* (19 mm), *B. subtilis* (19 mm), and *P. aeruginosa* (21 mm) [85].

Aqueous extracts from seeds and callus also shown strong and callus also shown strong antibacterial action, particularly against *Salmonella typhi* (16 ± 20 mm) and *Escheria coli* (22 ±0.5 mm). the callus extract shown a less potent antifungal effect than the seed extract [86-88]. Fumonin, a protein with significant antibacterial qualities, was generated by *Clitoria ternatea* seeda [89]. Finotin, another protein shown potent and wide range antifungal activity number of plant disease including *Bipolaris oryzae, Rhizoctonia solani, Fusarium solani,* and *Colletotrichum lindemuthianum* [90]. Additionally, it decreased the growth of two bean pests, *Acanthoscelides obtectus* and *Zabrotes subfasciatus*, and successfully inhibited *Xanthomonas axonopodis pv. phaseoli,* which causes bean bacterial blight [112].

3.2.2. Anthelmintic activities

There have been numerous studies published on the antihelmintic activity of *Clitoria ternatea* [102-107]. The crude alcoholic extract of *Clitoria ternatea*, together with its ethyl acetate and methanol fractions, considerably displayed paralysis and caused worm mortality as compared to the conventional reference piperazine citrate [102]. Aqueous and methanol *Clitoria ternatea* leaf extracts were tested for their ability to suppress free-living nematodes [103, 104]. In another research, *Clitoria ternatea* blooms, leaves, stems, and roots were examined for their ability to inhibit the growth of adult Indian earthworms, namely Pheretimaposthuma [102]. Methanol root extract is the most efficient and takes the least amount of time to kill and paralyze worms when compared to other extracts [102]. The power increases from blooms to leaves to stems to roots. The anthelmintic action of the *Clitoria ternatea* root's methanol extract may be due to the active ingredients in the extract [103-107].

3.2.3. Larvicidal activities

The most promising mosquito larvicidal action was demonstrated by *Clitoria ternatea* [108, 109]. *Anopheles stephensi*, *Anopheles aegypti*, and *Culex quinquefascitus* larvae were all successfully inhibited by *Clitoria ternatea* seed extract methanol extract, with LC50 values of 65.2, 154.5, and 54.4 ppm for each species, respectively [109]. In addition, methanol extracts of *Clitoria ternatea* flowers have also shown significant larvicidal activity against Aedes mosquitoes, highlighting its potential as a bio-insecticide [108].

3.3. Cardiometabolic & Enzyme-related Activities

3.3.1. HMG-CoA reductase activity

After fast removal of liver tissue as feasible, a 10% homogenized mixture was made in a solution of saline arsenate [113]. Before centrifugation, The resulting mixture was separated from protein. with an equivalent amount of diluted $HclO_4$ and let to be stand for five minutes [114]. Freshly made hydroxylamine reagent (alkaline hydroxylamine reagent for HMG-CoA) was added to 1 milliliter of the filtrate [115]. After 5 minutes of mixing, 1.5 mL of $FeCl_3$ solution was added [116]. At 540 nm, the absorbance was measured 10 minutes later against an arsenate blank [83]. Mevalonate/HMG-CoA ratio was computed [119].

3.3.2. Reduced postprandial hyperlipidemia

Clitoria ternetea can reduce postprandial hyperlipidemia and elevate the antioxidant defenses in hyperlipidemia. According to the study which done by a randomized crossover trial, 6 male volunteers had a high-fat meal with alone or with 1g & 2g CTE. After six hours blood sample was taken and a relevant difference was seen in the iAUC, or incremental area under the curve for serum triglycerides of the high-fat meal and the high-fat meal along with 2g of CTE [43, 44]. The lipid-lowering efficacy of CTE extraction is due to the phenolic acids, polyphenols, and anthocyanins in CTE, particularly delphinidin derivatives, it lowers the pancreatic lipase, slowing the fat adsorption and digestion [44]. Apart from altering lipid metabolism, 2 g of CTE enhanced

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glutathione peroxidase (Gpx) activity, increased plasma ferric reducing antioxidant power (FRAP) and thiol levels, and reduced increases in malondialdehyde (MDA), a sign of lipid peroxidation [43]. These actions strengthened enzymatic antioxidant defense. Overall indication we got from the study; *Clitoria ternetae* is effective against postprandial hyperlipidemia and FFA surges and improve antioxidant status after high-fat meals, although its immediate effects on inflammation appear minimal [44].

3.4. Enzyme Inhibition activity (α-Amylase and α-Glucosidase)

The butterfly peas contain a variety of phytoconstituents. Among them are anthocyanins, flavonoids, and phenolic acids, among others. Previously mentioned phytochemicals are act on multiple biochemical sites relevant to metabolic, cardiovascular, and oxidative stress factors. With the help of π-π bonds, hydrogen bonds, hydrophobic interactions, or by altering enzyme conformation and in some cases complexing with the substrate the active compounds bound with the α-Amylase and α-Glucosidase enzymes, which break the carbohydrate molecules and convert them into the simple glucose compound for that reason the blood sugar level elevates and experience a glucose spikes. But the compounds binds with it and block the function of α-Amylase and α-Glucosidase) [45]. The crude lyophilized extract (CLE) reduced α-amylase activity by about 38% at 20 mg/mL and α-glucosidase activity by about 20% at 500 µg/mL, according to the study's in vitro tests) [46]. These substances included delphinidin-3-O-glucoside, procyanidin A2, and quercetin-3-rutinoside [47].

3.5. Anti-inflammatory / Analgesic Activities

Similar to *Clitoria ternatea* other medicinial species have shown significant anti-inflammatory analgesic, antipyretic activity in animal models supporting the broader pharmacological potential of plant-based extracts [137]. Anti-inflammatory and analgeisc activities of plant extracts are commonly evaluated using carrageenan-induced paw edema, hot plate, tail-flick and acetic acid induced writhing model [135]. Rat models were used to examine the anti-inflammatory properties of a methanolic extract from *Clitoria ternatea* Linn. roots. *Clitoria ternatea* flowers had noteworthy characteristics that reduce inflammation at both dosages (200 and 400 mg/kg weight of the individual) ($P<0.01$) [29, 38, 110]. *Clitoria ternatea* methanol extract exhibited strong antipyretic properties. Oral administration of *Clitoria ternatea* root methanol extract to rats was reported to prevent vascular permeability generated by acetic acid and to prevent rat paw oedema caused by carrageenin [29,33,42,135]. The tail clip technique and the acetic acid-induced writhing reaction were used to investigate its analgesic effectiveness in mice [30, 42, 110, 135]. In different research, the antipyretic properties of *Clitoria ternatea*'s methanol extract were tested in albino rats [38, 110]. The extract's antipyretic efficacy was similar to that the traditional analgesic-antipyretic drug Paracetamol (150 mg/kg) [33, 111].

3.6. Anticancer / Tumor-related Activities

According to recent findings, plants and their constituents may have the ability to reduce tumors and trigger apoptosis in cancerous cells [7,136]. Additionally, the widely popular herbal remedy may have the ability to interfere with the progression of the cell cycle, boost immunity, and inhibit tumor angiogenesis [84, 118, 120, 136]. Reports on the anti-carcinogenic or cancer-suppressive properties of several plant extracts show a strong correlation with the extracts from *Clitoria ternatea* [121, 48, 49]. It was discovered that the purified lectin might be useful in research on cancer [50].

Both pet-ether and ethanolic floral extracts' cytotoxic effects were assessed using the trypan blue dye exclusion technique in vitro (10, 50, 100, 200, and 500 g/ml) of *Clitoria ternatea* was investigated. Both extracts demonstrated considerable dose-dependent cell cytotoxicity. The concentration of 10 g/ml petroleum ether extract exhibited an 8% reduction in cell count, but the content of 500g/ml had show a 100% reduction. In the instance of ethanolic extract, 10 g/ml concentration reduced cell count by 1.33%, whereas 500 g/ml concentration reduced cell count by 80% [52, 53, 54].

In an investigation on the lethality of brine shrimp, in a simple methanol extract, *Clitoria ternatea's* stem bark, seeds, and leaves showed strong toxic action against living-cell [113]. The crude methanolic extracts of leaves, seeds, and stem bark had respective LC50 values

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of 25.82, 110.92, and 179.89 gm/ml. Crude methanolic extract and leaf methanolic fraction showed very encouraging cytotoxic activities [121, 54, 56].

Clitoria ternatea anticancer efficacy was tested in mice with Dalton's lymphoma (DLA). The intraperitoneal injection of DLA cells caused tumors in mice [14]. For 14 days after tumor inoculation, *Clitoria ternatea* methanol extract (MECT) was administered at dosages of 100 and 200 mg/kg body weight. Evaluations of MECT's impact included peritoneal cell count, survival duration, in vitro cytotoxicity, hematological studies, and antioxidant characteristics. Viable count, packed cell volume, and tumor volume were all decreased with MECT therapy. Additionally, it raised the average survival time and non-viable cell count, prolonging the EAC mice's lifespan. The hematological profile in the treated group rebounded to values that were essentially normal [48, 49, 54, 55, 57].

3.7. Diuretic and anti-urolithiasis effect

The excretion of potassium and sodium in the urine increased moderately after intravenous dosages of the extract, but renal injury was also evident [19]. Dogs did not exhibit appreciable diuresis or natriuresis when given a non-toxic dosage of *Clitoria ternatea* roots or their 95% alcoholic ectract orally. The titrimetric method was employed to investigate how various *Clitoria ternatea* extracts prevented the in vitro development of calcium oxalate crystals, which are a common primary component of the majority of urinary stones [58, 59]. The inhibitory potency of *Clitoria ternatea* alcoholic extract was shown to be compared to Cystone (a patented medication used to dissolve kidney stones). An alcohol extract from *Clitoria ternatea* leaves suppressed calcium oxalate crystallization more efficiently than cystone (90.551.27%) in vitro when it came to the development of calcium oxalate precipitation [58, 22]. Recent studies further demonstrate that aqueous and methanolic extracts of *Clitoria ternatea* show significant diuretic activity and renal protective effects in animal models [59-62].

3.8. Anti-oxidant activity

Oxidative stress has been shown to be one of the main causes of many chronic and degenerative [98, 63, 138]. The antioxidant qualities of *Clitoria ternatea* petals have been demonstrated [64, 92]. In Thailand, flower extracts from *Clitoria ternatea* are utilized in cosmetic goods as antioxidants [63, 97]. *Clitoria ternatea* aqueous leaf extracts were examined for their antioxidant properties potential by counting the amounts of enzymatic and non-enzymatic antioxidants. The diphenypicrylhydrazyl (DPPH) assay, hydroxyl radical scavenging activity, ferric reducing power assay (FRAP), and reducing activity assay were among the various assays used to determine the antioxidant capability in vitro [93, 100, 64, 68, 138]. The outcomes were similar to those of common antioxidants such as rutin, ascorbic acid, and butylated hydroxyl toluene (BHT) [68, 100, 101].

4. TOXICOLOGICAL STUDIES:

Pharmacological efficacy and toxicological safety are intimately related in medicinal plant research because bioactive phytoconstituents that have antibacterial, anti-inflammatory, and antioxidant properties may also cause negative reactions at extended exposure [129, 132, 133]. Despite being considered safe at conventional doses higher doses exposure results in detectable organ specific toxicity; therefore systemic toxicological evolution is essential to establish the safety profile of herbal medicines [134, 136]. At a normal or conventional level, the *Clitoria ternatea* is typically harmless. Although higher dose exposure results in detectable organ-specific toxicity [37]. The most toxic plant part is the root extract, acute oral administration in mice showed a very high LD 50 of about 32118 mg per kilogram, but those above 2500 mg/kg cause severe cholinergic symptoms, including tremors, convulsions, sedation, cyanosis, respiratory difficulties, as well as, in some cases, Nephrotoxicity and hepatotoxicity are found by histopathological tests [135]. Methanolic leaf extracts, on the other hand, demonstrated a favourable safety margin, showing weak toxicity in the brine shrimp assay up to 24 hours and moderate toxicity only at 48 hours. Additionally, minimal acute toxicity with an LD_{50} higher than 2000 mg/kg. There were no pathological lesions on major organs, supporting their relative safety under normal usage conditions [137]. Flower extract also showed very low acute toxicity, with an LD50 greater than 2000 mg/kg for 14 days, clearly damaged the liver and Kidneys, hepatocyte degeneration, vacuolation,

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necrosis, and inflammation, renal tubular degeneration, while lower doses (500-1000 mg/kg) did not cause any notable histological abnormalities [138]. All things considered, the evidence that is currently available so that *Clitoria ternatea* is safe at standard doses but may cause hepatic, renal, and neurobehavioral toxicity at high experimental doses, especially with root and high-dose flower extract, which highlights the necessity of appropriate dosing in therapeutic applications.

5. DISCUSSION

This review consolidates and interprets the current pharmacological evidence on *Clitoria ternatea*, linking its rich phytochemical composition to its wide range of biological activities. The distribution of bioactive compounds varies across different plant parts, contributing to distinct therapeutic effects. The roots predominantly contain triterpenoids such as taraxerol and taraxerone, which are widely associated with anti-inflammatory and hepatoprotective properties. Leaves and seeds are rich in flavonoids, alkaloids, and fatty acids, supporting their demonstrated antioxidant and antimicrobial activities. Notably, the flowers represent the most phytochemically distinctive portion of the plant, owing to their high content of polysacylated anthocyanins known as ternatins. These compounds not only impart the characteristic blue pigmentation—making the flower a valuable natural colorant—but also contribute significantly to antioxidant, anti-inflammatory, anti-diabetic, and neuroprotective effects. This review summarizes scientific work published over the period 1990–2026. The overall percentage of research work reported of *Clitoria ternatea* is shown in **Figure 2.**

Traditionally esteemed as a brain tonic, *C. ternatea* has been validated through modern research for its nootropic and neuroprotective properties. Studies have demonstrated enhancement in memory and learning, preservation of acetylcholine levels, and modulation of neurotransmitter pathways involved in anxiety, depression, and seizure control. Beyond central nervous system activity, the plant exhibits noteworthy metabolic benefits. Anti-diabetic effects have been attributed to the inhibition of carbohydrate-digesting enzymes (α-amylase and α-glucosidase), while its anti-hyperlipidemic activity is linked to the action of polyphenolic constituents—particularly delphinidin derivatives—that reduce lipid absorption and oxidative stress. Additionally, *C. ternatea* shows broad antimicrobial, antiparasitic, and larvicidal activities, with specific proteins such as finotin offering promising applications in both medical and agricultural sectors. Preliminary anticancer findings, including dose-dependent cytotoxicity and increased survival in tumor-bearing models, further highlight its therapeutic potential; however, the specific bioactive constituents and molecular pathways underlying these effects require deeper investigation.

Among the pharmacological activities reviewed, the anti-inflammatory and nootropic effects appear particularly promising for future therapeutic development. However, significant challenges remain. The most critical limitation is the lack of extract standardization due to complex and variable phytochemical profiles. Differences in extraction solvents lead to major variations in the chemical composition of the final extract; for instance, anthocyanin-rich flower components are more efficiently recovered in alcoholic extracts, whereas aqueous extracts tend to be richer in phenolics. Standardization based on defined chemical markers—such as ternatins for flowers and taraxerol for roots—will be essential to ensure reproducibility across studies and potential clinical applications.

Furthermore, the majority of available evidence is preclinical, derived from in vitro and animal studies. To advance *C. ternatea* from experimental exploration to evidence-based therapeutic use, well-designed clinical trials are necessary to confirm efficacy, establish optimal dosage regimens, and evaluate long-term safety in humans. Although traditional usage suggests favorable tolerability, comprehensive toxicological assessments remain essential to fully define its safety profile.

Overall, while *Clitoria ternatea* demonstrates considerable therapeutic promise supported by a diverse phytochemical foundation, future research must prioritize extract standardization, mechanistic elucidation, and rigorous clinical validation to facilitate its translation into clinically relevant formulations.

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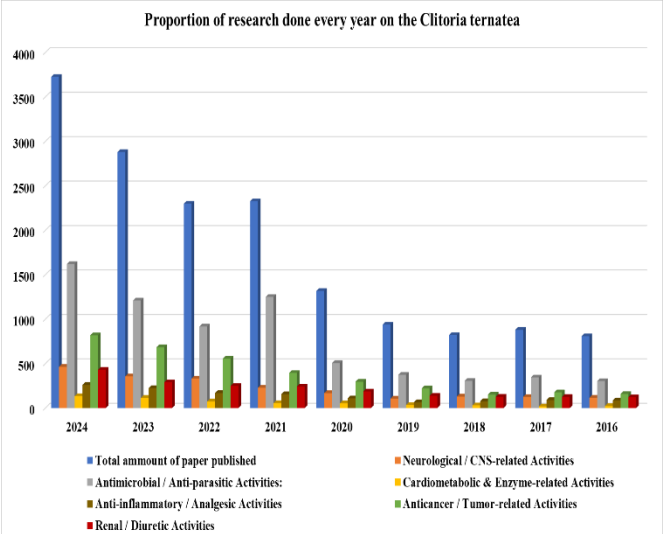

Figure 2: The total percentage of research work provided for the estimation of *Clitoria ternatea*

6. CONCLUSION

Clitoria ternatea, commonly referred to as butterfly pea or blue tea, emerges as a highly valuable medicinal plant having a wide range of pharmacological and therapeutic potentials. This comprehensive review highlights its diverse phytochemical composition and the wide array of biological activities it possesses, establishing it as a promising candidate for the development of plant-based therapeutic agents. Traditionally used in Ayurvedic and folk medicine systems, the plant has gained significant scientific interest in recent years due to its bioactive compounds such as flavonoids, anthocyanins, triterpenoids, and alkaloids. This review comprehensively encompasses research studies and pharmacological findings on *Clitoria ternatea* published between 1990 and 2026.

Numerous investigations have verified the plant's potent antioxidant properties, mainly credited to its abundant anthocyanin content. These antioxidants perform a vital role in neutralizing free radicals, thus providing anti-aging, anti-inflammatory, and protective cardiovascular benefits. Furthermore, *Clitoria ternatea* displays significant antimicrobial activity against numerous bacterial and fungal pathogens, making it a possible natural substitute for synthetic antibiotics, particularly amidst growing antimicrobial resistance.

Another significant pharmacological aspect of *Clitoria ternatea* is its nootropic and neuroprotective benefits. Extracts from the plant have been demonstrated to improve memory and cognitive function, suggesting potential for treating neurodegenerative diseases like Alzheimer's. This effect is thought to arise from the modulation of cholinergic function and the suppression of acetylcholinesterase, which are essential for learning and memory.

Furthermore, *Clitoria ternatea* exhibits considerable anti-diabetic, anti-inflammatory, anti-cancer, and anti-stress properties. The hypoglycemic effect seen in experimental research validates its traditional use for diabetes control, and its ability to lessen inflammation could offer benefits for managing chronic inflammatory conditions. Its anti-cancer potential, while still in preliminary research stages, is encouraging due to the triggering of apoptosis and suppression of cancer cell growth by specific phytoconstituents.

The plant also demonstrates potential for wound repair, diuretic action, hepatoprotective benefits and as an anti-asthmatic treatment. These diverse pharmacological properties not only validate its traditional uses but also create new pathways for pharmaceutical development. The minimal toxicity and few side effects noted in preclinical studies additionally support its appropriateness for long-term usage.

Despite these promising results, there are constraints and gaps in existing research that must be resolved. Most studies have been performed in vitro or on animal models, and therefore, human clinical studies needed to verify efficacy and safety. Also, standardization of extracts pinpointing of bioactive constituents, and comprehension of mechanisms of action are fields needing more investigation.

In summary, *Clitoria ternatea* possesses great potential as an origin for novel therapeutic agents with more scientific validation and clinical investigation, this versatile hers could contribute greatly to modern pharmacotherapy and integrative health. Its holistic health advantages, merged with traditional knowledge and modern scientific support, position it as a leading

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contender in the field of medicinal plants with diverse therapeutic potential.

CONFLICT OF INTEREST

Authors declare no conflict of interest.

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