**Biological activities and phytochemicals of clitoria*ternatea***

**(Butterfly pea)**

Sakshi Singh Babita Agrawal\*(Associate ProfessorHOD)

C.M.P. Degree College(211002),Prayagraj C.M.P. Degree College(211002), Prayagraj

(University of Allahabad) (University of Allahabad)

Prayagraj, India Prayagraj, India

Email:[**babitaprashantagrawal@gmail.com**](mailto:babitaprashantagrawal@gmail.com)**.**

**ABSTRACT**

Clitoria*ternatea*, also called the "Butterfly Pea, Blue pea, Darwin pea" has long been used in Ayurvedic medicine to treat conditions like constipation, indigestion, arthritis, skin ailments, liver and digestive troubles, and indigestion. Many diseases are treated using the flowers, leaves, bark, roots, stems, and other components of C. *ternatea*. Worldwide, C. *ternatea* is used as a culinary colourant and as an attractive flower. Recent developments in biology and phytochemicals from C. *ternatea* plants are featured in this book chapter. From C. *ternatea* flowers, a number of phytochemicals have been extracted, including anthocyanins, kaempferol, quercetin, and myricetin glycosides. Clitoriaternatea flower extracts were discovered to have health-promoting antibacterial, antioxidant, anti-inflammatory, cytotoxic, and antidiabetic properties. Clitoria*ternatea* flower has a wide spectrum of pharmacotherapeutic qualities, is safe and effective, and is a viable option for functional food applications.

**Keywords-** Clitoriaternatea, Phytochemicals, Biological process, Anthocyanins.

1. **INTRODUCTION**

Since ancient times, people of all civilizations and cultures have used aromatic and medicinal herbs for therapeutic, religious, cosmetic, nutritional, and beautifying purposes[1-2]. Clitoria*ternatea* is a species of plant that belongs to the family Fabaceae, the phylum Tracheophyta, the class Magnoliopsida, and the kingdom Plantae [3].Clitoria*ternatea*, a perennial climber that grows to a height of 2 to 3 metres, is also known as the blue pea or butterfly pea flower. [4]Southeast Asia has long utilised the blue flower pigment as a food colouring, but it is also often planted as an ornamental plant and used as a species for revegetation [5–6]. The plant's suitability as a cover crop and green manure is well acknowledged; in addition to suppressing perennial weeds, it can also fix nitrogen to replenish the soil [7-8].

In Madagascar, South and Central America, the Caribbean, India, the Phillipines, and other tropical Asian countries, the C. *ternatea* plant is widely dispersed[9-10].Clitoria*ternatea* is recognised as a nootropic plant in Ayurvedic medicine[11]. It does well in places that receive both direct sunlight and moderate shade. While flowering takes place in 4 weeks, seed germination typically occurs in 1-2 weeks [12–13]. The 4-5 cm long flowers of the several C. ternatea lines come in a range of hues, including light blue, dark blue, white, and mauve (Figure. 1). It is believed that the blooms include ternatin anthocyanins, various flavanol glycosides of kaempferol, quercetin, and myricetin, among other compounds [14-15]. The leaves are 5-7 leaflets long and eliptic-oblong in shape. Their dimensions range from 2.5 to 5.0 cm in length and 2.0 to 3.2 cm in breadth. Their very flat, linear, beaked seed pods, which are about 5-7 cm long, are tasty. The oval-shaped seed is 3–4 mm wide and 4.5–7.0 mm long. Its colour is a blackish or yellowish brown. It features a taproot system with several thin lateral roots [16-17].



**Figure 1: Flower of Clitoriaternatea**

Nutritional analysis of C. *ternatea* flowers revealed that they had a moisture content of 92.4% and percentages of 2.1, 0.32, 2.2, and 2.5% for fibre, protein, carbohydrate, and fat, respectively. The flower was also found to have significant amounts of magnesium (2.23 mg/g), potassium (1.25 mg/g), sodium (0.14 mg/g), zinc (0.59 mg/g), calcium (3.09 mg/g) and iron (0.14 mg/g) [18]. Several studies looked at, recognised, and isolated the bioactive components from C. ternatea flower. The blue ternatin anthocyanins are classified as anthocyanins since they are acylated on the basis of delphinidin. (Figure. 2).



**Figure 2: Delphinidin 3-malonyl glucoside**

Ayurvedic medicine has traditionally employed Clitoria*ternatea* for a number of medical conditions. Its seeds can help with constipation, colic, and inflamed joints. Indigestion, constipation, fever, arthritis, sore throat, skin conditions, and eye conditions are all treated using its rootsTo induce uterine contractions, promote menstruation, treat liver and intestinal problems, and promote menstruation, traditional Cuban medicine uses a decoction of the roots alone or in combination with flowers [20-21]. On the Seed, fruits, roots, flowers, and leaves of C. *ternatea*, numerous research studies have been conducted. Numerous research have demonstrated that the crude extract from the Clitoria*ternatea* flower has antidiabetic[22], antioxidant[23], antibacterial[24], and antiproliferative/anticancer [25] properties.As a result, In the food and pharmaceutical industries, C. *ternatea* flowers can be used as a supplement or a natural source of antioxidants. This study summarises the most recent information on C. *ternatea* flower extraction techniques, their impact on the phytochemicals, and the biological actions of these phytochemicals.The most recent information on C. *ternatea* plants, their impact on phytochemicals, and the biological functions of these phytochemicals are included in this book chapter.

1. **BLUE PEA FLOWER ANTHOCYANINS**

The blue pea bloom, Clitoria*ternatea* L., is a rich source of polyacylated anthocyanins, which can be exploited as a natural food colour since they are more stable than non-acylated anthocyanins [26–27]. The pH has an impact on the colour of anthocyanin extracts from blue pea flowers, just like it does for other anthocyanins. Between pH levels 3.2 and 5.2, violet turns blue, between pH levels 5.2 and 8.2, light blue is present, and between pH levels 8.2 and 10.2, light blue turns dark green. Red is present at pH levels below 3.2 [28]. Both the changed H and OH concentration in the medium and structural alterations in anthocyanin molecules may be to blame for this colour change. The neutral quinoidal base gives the blue colour, the flavylium ion gives the red hue, and the ionic chalcone gives the green tint. Non-acylated anthocyanins' flavylium ion transforms into the colourless carbinol pseudo basic when the pH increases. However, the acyl groups in blue pea flower anthocyanins prevent the hydrolysis of the flavylium ion to the less stable carbinol pseudo basic form, producing the blue colour quinoidal instead, which has a lesser susceptibility to pH changes in slightly acidic or neutral medium. As a result, blue pea flower anthocyanins could be used as a blue colouring agent in both acidic and neutral food systems. The blue pea blossom, Clitoria*ternatea* L., is a rich source of polyacylated anthocyanins. These anthocyanins have the advantage of being used as a natural food colouring additive since they are more stable than non-acylated anthocyanins [29]. The pH has an impact on the hue of the blue pea flower anthocyanin extract, just like it does for other anthocyanins. Below pH 3.2, red is present, between pH 3.2 and 5.2, violet turns to blue, between pH 5.2 and 8.2, light blue is present, and between pH 8.2 and 10.2, light blue turns to dark green. Both the changing H+ and OH- concentration in the medium and the structural change in anthocyanin molecules may be to blame for this colour change. The existence of the flavylium ion, the neutral quinoidal base, and the ionic chalcone are what give the colour its red, blue, and green hues, respectively [30]. Non-acylated anthocyanins' flavylium ion transforms into the colourless carbinol pseudo basic when the pH increases. The anthocyanins in blue pea flower acyl groups, however, prevent the hydrolysis of the flavylium ion into the less stable carbinol pseudo basic form, leading in the development of the blue colour quinoidal, which is less sensitive to pH changes in moderately acidic or neutral medium [31-32].As a result, blue pea flower anthocyanins could be used as a blue colouring agent in both acidic and neutral food systems.

1. **OTHERS PHYTOCHEMICALS**
2. **Flavonoids**

Flavonoids, such as anthocyanins (such as delphinidin, cyanidin, and petunidin) and flavonols (such as quercetin, kaempferol, and myricetin), are abundant in Clitoria*ternatea*. These substances have anti-inflammatory and antioxidant capabilities, and they help the flowers' blue and purple coloration. The most notable flavonoids in this plant include anthocyanins like delphinidin and cyanidin as well as flavonols like quercetin and kaempferol.

1. **Alkaloids**

Clitoria*ternatea* contains alkaloids, which are organic compounds that often have pharmacological activities. The major alkaloid identified in the plant is called "clitorine." Alkaloids can exhibit a range of biological effects, but their specific activities in Clitoria*ternatea* are still being studied.

1. **Triterpenoids and Sterols**

Clitoria*ternatea* has been found to contain various triterpenoids and sterols. These compounds are known for their diverse biological activities, including antidiabitic, antioxidant, and anti-inflammatory properties.

1. **Saponins**

Saponins are glycosides with soap-like properties. Clitoria*ternatea* contains certain saponins, which have exhibited various biological activities, including antifungal and antimicrobial effects.

1. **CLITORIA *TERNATEA'S* BIOLOGICAL PROCESSES**

The flower of the Clitoria*ternatea* contains a large number of phytochemicals that have excellent antioxidant, antibacterial, anti-diabetic, anti-inflammatory, and antiproliferative/anticancer effects [38–42]. Acute toxicity research utilising albino Wistar rats administered orally with an aqueous ethanol extract of the flower (2000 mg/kg bodyweight) showed no evidence of abnormality or mortality, and the haematological results were not significantly different. The extract is safe to consume and did not exhibit any acute adverse effects [43]. Flowers of Clitoria*ternatea* may be used as a functional food added to other food products or even as a medicinal supplement or pill coupled with brand-name medications to increase patient treatment effectiveness.

1. **Antioxidant properties**

Flavonoids, anthocyanins, and other polyphenolic chemicals, which are strong antioxidants, are abundant in the plant species Clitoria*ternatea*. Free radicals are unstable chemicals that can harm cells through oxidative stress, speed up ageing, and cause a number of diseases. Antioxidants aid in the neutralisation of free radicals. Clitoria*ternatea's* antioxidant properties may shield cells and tissues from oxidative damage and promote general health.[44-45].Several studies have looked at the antioxidant activity of C. *ternatea* flowers using antioxidant assays like 2,2-diphenyl-1-picrylhydrazyl radical (DPPH) radical scavenging, ferric reducing antioxidant power (FRAP analysis), hydrogen peroxide scavenging, hydroxyl radical scavenging activity (HRSA analysis), , oxygen radical absorbance capacity (ORAC analysis), superoxide radical scavenging activity (SRSA analysis), and ferrous ion. In the DPPH experiment, it was discovered that the 100% methanol extract of the C. ternatea flower was more effective than vitamin E whereas the water extract of the plant was shown to be weaker than ascorbic acid (vitamin C). In one study, the antioxidant activity of extracts produced using various solvents was examined and compared; after 15 minutes of extraction, it was shown that the water extract was superior to the 100% ethanol extract in terms of antioxidant activity (DPPH analysis) [50].

Recent study that established the best extraction time for the three extracts—six hours—found that the water extract and 50% methanol were equally strong and had more activity than the 100% methanol extract[51].

1. **Nootropic effects**

Nootropics are medicines that may boost cognitive processes like learning, reminder, and focus. They are frequently referred to as "smart medications" or cognitive enhancers. Clitoria*ternatea* has a long history of use as a brain tonic and is said to improve cognitive functioning. Clitoria*ternatea* extracts may have memory-improving effects, according to certain research, which is probably due to the presence of specific chemicals that may improve brain health.

1. **Anxiolytic and antidepressant effects**

Clitoria*ternatea* has been traditionally used for its calming and mood-enhancing properties.Preclinical studies in animals have shown that Clitoria*ternatea* extracts may have anxiolytic (anxiety-reducing) and antidepressant effects, possibly due to interactions with neurotransmitter systems in the brain.

1. **Antimicrobial activity**

The antibacterial activity of Clitoria*ternatea* extracts against many microorganisms, including bacteria, fungi, and even some viruses, has been the subject of numerous research. Alkaloids, tannins, and flavonoids, among other bioactive components of the plant, are thought to be in charge of the plant's antibacterial properties.

For instance, a 2015 study reported in the Journal of Traditional and Complementary Medicine revealed that the leaf extract of Clitoria*ternatea* was highly effective against both Gram-positive and Gram-negative bacteria. Another study in the Journal of Pure and Applied Microbiology in 2017 demonstrated its antifungal properties against various pathogenic fungi.

Moreover, researchers have also explored the antiviral potential of Clitoria*ternatea*. A 2018 study in the Journal of Ethnopharmacology revealed that the plant extract displayed inhibitory effects against the herpes simplex virus.

The development of natural antimicrobial drugs is made possible by Clitoria*ternatea's* antibacterial action, which may also help treat a number of infectious disorders. To completely comprehend its methods of action and to confirm its promise in therapeutic applications, more study is necessary.

1. **AntiinflamatoryActivity**:

The body's natural defence mechanism against hazardous stimuli is inflammation. Chronic inflammation, however, can result in a number of medical issues. According to certain research, Clitoria*ternatea* extracts contain anti-inflammatory properties that may be useful for treating inflammatory diseases. The currently available non-steroidal anti-inflammatory drugs (NSAIDs), such as acetaminophen and aspirin, are associated with side effects, primarily gastrointestinal and cardiovascular issues because they are known to affect both COX-1 and COX-2[55]. To lessen the hazards associated with NSAIDs while providing adequate pain management, new or alternative approaches must be found. Using the carrageenan paw edoema method, the petroleum ether extract of C. *ternatea* flowers was evaluated for its ability to reduce inflammation in healthy albino rats of both sexes. In Eddy's hot plate method, the therapy group (400 mg/kg) considerably outperformed the untreated control group in terms of reaction time, which is measured as the amount of time it took an animal to lick its front or back paws or to leap in response. In comparison to the untreated control group, the extract (400 and 200 mg/kg) dramatically reduced paw edoema. The study suggests that the extracts may have a protective effect against the release of prostaglandins, kinnins, and other compounds in carrageenan-induced edoema[56].

1. **Anti-diabetic potential**

Research has shown that extracts from Clitoria*ternatea* have the ability to lower blood glucose levels by improving insulin levels sensitivity and stimulating glucose uptake in cells. Additionally, it may help preserve pancreatic beta-cell function, which is responsible for insulin production, thereby improving overall glucose control[57]. Furthermore, Clitoria*ternatea* has been found to mitigate diabetic complications such as diabetic nephropathy and retinopathy due to its protective effects on kidney and retinal tissues[58].

Although promising, it is essential to note that the majority of studies have been conducted on animals or in vitro, and human clinical trials are limitedTherefore, more investigation is needed to confirm and comprehend the anti-diabetic potential in Clitoria*ternatea*[59]. Recently Studies have explored the potential anti-diabetic effects of Clitoria*ternatea* extracts.Compounds in the plant may help reduce blood glucose levels and enhance insulin sensitivity, making it potentially useful in managing diabetes[60].

1. **Wound healing**

Clitoria*ternatea*has been traditionally used for wound healing.The plant's anti-inflammatory and antioxidant qualities could be useful in tissue repair and wound healing.current research on Clitoria*ternatea's*wound healing potential is promising, it is essential to note that most studies have been conducted in animal models or in vitro. Further clinical research and human trials are necessary to fully validate the efficacy and safety of Clitoria*ternatea* for wound healing applications.

1. **Anti bacterial Activity**

Modern treatments are significantly less effective due to the emergence of bacteria that are resistant to antibiotics, which results in the failure of infection treatment[62]. Modern treatments are significantly less effective due to the emergence of bacteria that are resistant to antibiotics, which results in the failure of infection treatment. There are several ways to test an antimicrobial agent's (antibacterial or antifungal) in vitro activity, including the disc diffusion method and broth or agar dilution[63].Numerous studies looked into the ability of C. *ternatea* flowers to fight germs. When tested against 12 bacterial species. Twelve bacterial species were tested against the methanol extract of the C. *ternatea* flower (Klebsiella pneumoniae,Bacillus cereus, Streptococcusfaecalis, Escherichia coli, Bacillus thuringiensis, Herbaspirillum spp., Pseudomonas aeruginosa, Staphylococcus aureus, Salmonella typhi, Enterobacteraerogens, Proteus mirabilis and Bacillus subtilis) It was discovered to have the strongest activity against Bacillus thuringiensis utilising the agar disc diffusion technique with a minimum bactericidal concentration(MBC) of 25 mg/mL and minimum inhibitory concentration(MIC) of 12.5 mg/mL with an inhibition zone of15.7 mm [64]. In a different investigation, the antibacterial activity of a flower extract from C. ternatea (4 mg) against P. aeruginosa, S. enteritidis,S. typhimurium, K. pneumoniae, and E. coli was examined. The extract was tested in methanol,water, hexane, chloroform , and petroleum ether.Using the agar disc diffusion technique, the methanol extract was found to have the highest activity, with an inhibitory zone ranging from of 16–26 mm for K. pneumonia, P. aeruginosa, and E. coli, while it had no effect on S. typhi and S. enteritidis. K. pneumonia and P. aeruginosa showed the maximum zone of inhibition, measuring 26 mm[65]. The ethanol extract paste of the C. *ternatea* flower contains anthocyanins that have antibacterial action against B. subtilis subsp. spizizenii, B. cereus, Yersinia enterocolitica, E. coli, B. subtilis, S. aureus, Proteus mirabilis, and B. subtilis subsp. spizizenii. In recent study, the anthocyanin fraction obtained from the ethanol extract of the C. *ternatea* flower had the best effect against B. subtilis with a disc diffusion inhibition zone of 10 mm, while in another investgation, it had the best effect with a minimum inhibitory concentration (MIC) of 1.6 mg/mL and a minimum lethal concentration (MLC) of 25 mg/mL.[66].

1. **anticancer activities and Cytotoxic and anti-proliferative**

Among the methods used to treat and manage cancer include radiation therapy, targeted therapy and chemotherapy, however these treatments do not offer a permanent cure and have a number of toxicities and side effects. [67]. Therefore, there is an urgent need for new agents that are secure, accessible, and efficient. Several studies looked into the anticancer potential of C. ternatea flowers that were extracted using different solvents. The 100% petroleum ether extract (IC50=36 g/mL) was found to be more effective compared to the 100% ethanol extract (IC50 value of 57 g/mL) in the in vitro cytotoxic experiment against Dalton's lymphoma ascites (DLA) cells at 3 h, which may be related to the unique phytochemical content of both of the extracts. The petroleum ether extract was found to include triterpenoids, saponins, steroids, and tannins, while the ethanol extract only contains flavonols. [68].The hydrophilic (100% methanol) extract demonstrated a more potent anticancer effect on the human epithelial laryngeal carcinoma (Hep-2) cell line than the lipophilic (1:1, ethyl acetate: hexane) extract [69]. The hydrophilic extract's potent active ingredients were mostly ternatins, kaempferol, and quercetin, which are important for the antiproliferative effect, as opposed to the lipophilic extract, which is composed of tocopherols, phytosterols, and fatty acids. flower extract with anti-diabetic properties. With the highest effect occurring at day 28 (49.4% at 1 mg/mL), the water extract considerably reduced the level of fructosamine in glycated bovine serum albumin (14.47-36.66%) as well as the production of fluorescent advanced glycation end products. The extract's ability to scavenge free radicals, which is primarily due to the presence of the active ingredients kaempferol, delphinidin derivatives, and ternatinanthocyanins,, may be how it is able to inhibit the formation of advanced glycation end products, the study claims. [70]. These investigations combined suggested that the flavonoid and alkaloids components of the extract (flavonol, glycosides, and anthocyanins) may have hypoglycemic effects by aiding the transport of blood glucose from peripheral tissues to the plasma or by enhancing insulin secretion from the -cell.

1. **Diuretic and anti urolithiasis effect**

When given orally in a non-toxic dose, There was no observable diuretic or natriuretic effect on dogs from the roots of Clitoria*ternatea* or their extract in 95% alcohol. Although intravenous doses similarly slightly improved the excretion of salt and potassium in urine, the extract showed signs of kidney damage. [71]. By using a titrimetric method, it was determined whether different Clitoria*ternatea* extracts might suppress the in vitro development of calcium oxalate crystals, which is a common primary component of most urinary stones. it was found that Cystone, a patented drug for the elimination of kidney stones, had an inhibitory power that was comparable to the alcohol extract of Clitoria*ternatea*. Studies conducted in vitro utilising an alcohol extract of the leaves of Clitoria*ternatea* showed better calcium oxalate crystallisation inhibition (72.991.2%) compared with cystone (90.551.27%). [72].

1. **CONCLUSION**

The edible blue pea flower, also called Clitoria*ternatea*, is significant both aesthetically and therapeuticallyNumerous polyacylated anthocyanins, which are more stable compared to non-acylated anthocyanins, can be found in the blue pea flower. Anthocyanins from blue pea flower exhibit a highly vivid and uniform blue colour in acidic medium, making it easier to use them as a blue food colouring agent in acidic food systems.Many different pharmacological effects of Clitoria*ternatea* have been reported, including memory improvement, increased acetylcholine levels, antipyretic, nootropic, anticonvulsant, tranquillizing, antistress, anxiolytic, antidepressant, sedative, antimicrobial, local anaesthetic, antidiabetic, insecticidal, anti-inflammatory, analgesic, diuretic, and blood platelet aggregation inhibition.There have been reports of numerous secondary metabolites from this plant, including anthocyanin glycosides, phytosterols, flavanoids, and pentacyclic triterpenoids. It can be utilised to improve memory and serve as a starting point for the creation of brand-new phytoceuticals that treat CNS disorders. There are currently no known very effective curative therapies for this indication. The mode of action of these bioactive elements has been uncovered in some investigations, and this information can be used to comprehend the biological effect that is responsible for its occurrence.In order to comprehend how the extract/active chemicals function in stimulating the biological response and how they might affect/modulate particular pathways/molecular targets in the human body, more research is necessary. In numerous investigations, the potential antioxidant activity of C. *ternatea* flowers has been shown in chemical, in vivo, and cell-based experiments. Future research comparing the impact on people with specific medical issues to subjects in good health is advised to better understand the impact and assess the potential. Because this flower offers so many advantages, to fully understand the biological effects that have already been identified and to investigate possible bioactivities, the indicated additional research must be carried out.In order to improve human health and wellness, the bioactive components of C. *ternatea* flowers present tremendous opportunities for study and development as cutting-edge pharmacological agents and applications as functional foods.

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