BIOLOGICAL ACTIVITIES AND PHYTOCHEMICALS OF CLITORIA*TERNATEA* (BUTTERFLY PEA)

Abstract

Clitoria*ternatea*, also called the "Butterfly Pea, Blue pea, Darwin pea" has been utilised for Ayurvedic medicine to treat conditions such as 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: Anthocyanins, Clitoriaternatea, Phytochemicals, Biological process,

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I. INTRODUCTION

Since ancient times, people of all civilizations and cultures have used aromatic and medicinal herbs for religious beautifying, therapeutic, nutritional and cosmetic applications [1-2]. Clitoria*ternatea* is a species of plant that is a member of the Fabaceae family, phylum Tracheophyta, the class Magnoliopsida, and the kingdom Plantae [3].Clitoria*ternatea*, a recurring climber it increases in height to 2 to 3 metres, is additionally called as the blue pea or butterfly pea flower or Darwin pea [4]. Southeast Asia has long utilised the betterfly flower using pigment as a food colouring, but additionally, it is frequently utilised as a species for revegetation and planted as an attractive plant [5–6]. It is widely recognised that the plant is a good choice for green manure and cover crops; 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 being a cognitive booster plant in Ayurvedic medicine [11]. This 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 dark blue, white, light blue and mauve (Figure. 1). It is believed that the blooms include various flavanol glycosides of kaempferol, quercetin, ternatin anthocyanins and myricetin, among other compounds [14-15]. The leaves are 5-7 leaflets long and eliptic-oblong in shape. Their dimensions scope from 2.5 to 5.0 cm in extent 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. It is either a blackish or a yellowish brown colour. It has a taproot system and multiple lateral roots that are thin. [16-17].

Figure 1: Flower of Clitoriaternatea

C. ternatea flower nutrition analysis 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. A flower was also discovered to have significant amounts of iron (0.14 mg/g)

magnesium (2.23 mg/g), sodium (0.14 mg/g), zinc (0.59 mg/g), calcium (3.09 mg/g) potassium (1.25 mg/g) and (0.14 mg/g) iron [18]. The bioactive elements from C. ternatea flower have been examined, identified, and isolated in numerous research. The anthocyanins blue ternatin is classified as anthocyanins since they are acylated on the basis of delphinidin (Figure. 2).

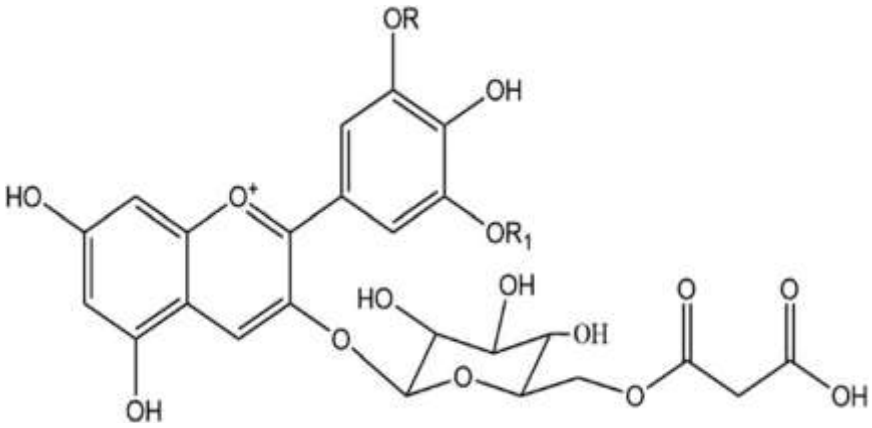

Figure 2: Delphinidin 3-Malonyl Glucoside

Ayurvedic medicine has traditionally employed Clitoria*ternatea* for a number of medical conditions. Its seeds can help with constipation, colic, and inflamed joints. Skin conditions, constipation, fever, Indigestion, arthritis, sore throat as well as eye conditions are all treated using its roots to induce uterine contractions, promote menstruation, treat liver and intestinal problems, and promote menstruation, A decoction of the roots alone or in conjunction with flowers is used for traditional Cuban treatment. [20-21]. On the Seed, fruits, roots, flowers and leaves (full plant) 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. A result, C. ternatea flowers can be used as a supplement or a natural source of antioxidants in the food and drug sectors. 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.

II. BLUE PEA FLOWER CLITORIA*TERNATEA* ANTHOCYANINS

Polyacylated anthocyanins, which are more stable than non-acylated anthocyanins and are found in abundance in the blue pea bloom, Clitoriaternatea L., are capable of being used as a natural food colour. [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 flavylium ion, a neutral quinoidal base, and an ionic chalcone are responsible for the red, green, and blue hues, respectively. When the pH rises, the flavylium ion of non-acylated anthocyanins changes into the colourless carbinol pseudo basic. However, the acyl groups in the

anthocyanins in blue pea flower prevent the hydrolysis of the flavylium ion to the less stable carbinol pseudo basic form, creating the blue colour quinoidal instead, which is less sensitive to pH fluctuations in slightly acidic or neutral medium. As a result, both acidity and basic food systems could use blue pea blossom anthocyanins as a blue colouring agent. Clitoriaternatea L., the blue pea bloom, is a great source of polyacylated anthocyanins. These anthocyanins have the advantage of being food colouring made from natural ingredients additive since they are more stable than non-acylated anthocyanins [29]. Similar to other anthocyanins, the pH affects the colour of the anthocyanin extracted from blue pea blooms. Below pH 3.2, red is give, between pH 3.2 and 5.2, blue turns to violet, between pH 5.2 and 8.2, light blue is available, between pH 8.2 and 10.2, light blue turns to dark green. This colour variation could be the result of the medium's fluctuating H+ and OH- concentrations as well as anthocyanin molecules' altered structural properties. The red, blue, and green colours of the colour are provided by the presence of the flavylium ion, a neutral quinoidal base, and the ionic chalcone, respectively. [30]. When the pH rises, the flavylium ion of non-acylated anthocyanins changes into the colourless carbinol pseudo basic. However, the anthocyanins in the acyl groups of the blue pea flower stop the hydrolysis of the flavylium ion into the less stable carbinol pseudo basic form, causing the production of the blue hue quinoidal, which is less sensitive to pH fluctuations in normal or mildly acidic medium. [31-32].As a result, Anthocyanins from blue pea flowers can be utilised as a blue food colour in both acidic and neutral food systems.

III. OTHERS PHYTOCHEMICALS

1. **Flavonoids**: Flavonoids, such as anthocyanins (such as cyanidin, delphinidin and petunidin) and flavonols (For example 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.

2. **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.

3. **Triterpenoids and Sterols**: Clitoria*ternatea* has been found to contain various triterpenoids and sterols. These substances are well-known for a variety of biological actions, including antidiabitic, antioxidant, and anti-inflammatory properties.

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

IV. CLITORIA *TERNATEA'S* BIOLOGICAL PROCESSES

The flower of the Clitoria*ternatea* contains a large number of phytochemicals (extract to plant) that have excellent antiproliferative/anticancer, antibacterial, anti-inflammatory, anti-diabetic and antioxidant effects [38–42]. Acute toxicity research utilizing albino Wistar rats administered by mouth with an extract of aqueous ethanol of the flower (2000 mg/kg

bodyweight) showed no indication of abnormality and mortality, The haematological results were little different from one another. The extraction is safe to consume and did not exhibit any acute adverse effects [43]. Clitoriaternatea flowers can be used as an edible additive to other foods or even as a dietary supplement or pill in combination with name-brand pharmaceuticals to improve the efficacy of patient therapy.

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 method, ferric reducing antioxidant power method (FRAP analysis), hydrogen peroxide scavenging, hydroxyl radical scavenging activity method (HRSA analysis), , oxygen radical absorbance capacity method (ORAC analysis), superoxide radical scavenging activity method (SRSA analysis), and ferrous ion. In the DPPH experiment, it was discovered that the 100% methanol extraction of the Clitoria ternatea blossom was additional effective than the vitamin E, while the water extraction of the plant be shown chosen weaker than vitamin C (ascorbic acid). In one study, the antioxidant activity of extracts produced using various solvents was examined and compared; after 15 minutes of extraction, In terms of antioxidant activity, it was established that the water extraction outperformed the 100% ethanol extraction. (DPPH analysis) [50].

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

2. **Nootropic Effects:** Nootropics are medicines that may boost cognitive processes like learning, reminder, and focus. They are frequently commonly known as "stylish medications" or cognitive enhancers. Clitoria*ternatea* has been used as a for a long time brain tonic and this 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.

3. **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.

4. **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, Gram-positive and Gram-negative bacteria were both effectively combated by a leaf extract of Clitoriaternatea. Its antifungal

activities against several pathogenic fungi were demonstrated in another study published in the Journal for Pure & Applied Microbiology in 2017.

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.

5. **Antiinflamatory Activity**:The body's natural defense 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 inflammatory illnesses may be treated with these substances' potential benefits.. Because they are known to influence both COX-1 and COX-2, the currently available non-steroidal anti-inflammatory medicines (NSAIDs), such as acetaminophen and aspirin, are linked to side effects, particularly gastrointestinal and cardiovascular problems. [55]. to lessen A hazards associated with NSAIDs while providing adequate pain management, new or alternative approaches must be found. Using the carrageenan paw edoema method, in healthy albino rats of both sexes, the petroleum ether extract of C. ternatea flowers was tested for its anti-inflammatory effects. According to Eddy's hot plate method, the treatment group (400 mg/kg) performed noticeably better than the untreated control group in terms of reaction time, which is calculated as the time it took an animal to lick its front or back paws or to leap in response. The extract (400 and 200 mg/kg) significantly decreased paw edoema in comparison to the untreated control group. According to the study, in carrageenan-induced edoema, the extracts could have an inhibitory effect against the release of prostaglandins, kinnins, and other substances.[56].

6. **Anti-Diabetic Potential:** Research has shown that extracts from Clitoria*ternatea* have the lowering of blood glucose levels by improving insulin levels sensitivity as well as 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]. The potential anti-diabetic properties of Clitoriaternatea extracts have recently been studied.The plant's constituents may improve the sensitivity of insulin and lower blood glucose levels, making it potentially helpful in the management of diabetes [60].

7. **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'*swound 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.

8. **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 extraction of the C. *ternatea* blossom (Klebsiella pneumoniae, Bacillus cereus, Streptococcusfaecalis, Escherichia coli, Bacillus thuringiensis, Herbaspirillum spp., Pseudomonas aeruginosa, Staphylococcus aureus, Salmonella typhi, Enterobacteraerogens, Proteus mirabilis and Bacillus subtilis) With a minimum bactericidal concentration (MBC) of 25 mg/mL and a minimum inhibitory concentration (MIC) of 12.5 mg/mL and an inhibition zone of 15.7 mm, it was shown to have the greatest activity against Bacillus thuringiensis using the agar disc diffusion technique [64]. 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 investigated in a different study. The extract was examined in hexane, chloroform, methanol, water, and petroleum ether.The methanol extract was found to have the highest activity using the agar disc diffusion method, with an inhibitory zone spanning from 16 to 26 mm for K. pneumonia, P. aeruginosa, and E. coli, but having no impact on S. typhi and S. enteritidis. P. aeruginosa and K. pneumonia displayed the largest zones of inhibition, each measuring 26 mm [65]. Yersinia enterocolitica, E. coli, B. subtilis, S. aureus, Proteus mirabilis, and B. subtilis subsp. spizizenii are all susceptible to the antibacterial effects of anthocyanins found in the ethanol extract paste of the C. ternatea flower. With a disc diffusion inhibition zone of 10 mm in a recent study, the anthocyanin fraction obtained from the ethanol extract of the C. ternatea flower had the best effect against B. subtilis. In another study, In another study, it had the most effective effect with a MIC (minimum inhibitory concentration) of 1.6 mg/mL and a least lethal level (MLC) of 25 mg/mL [66].

9. **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]. New agents that are secure, available, and effective are thus urgently needed. The potential for cancer prevention of C. ternatea blooms that were extracted using various solvents was investigated in a number of research. In the in vitro cytotoxic experiment against Dalton's lymphoma ascites (DLA) cells at 3 h, the 100% petroleum ether extract (IC50=36 g/mL) was shown to have been more successful than the completely ethanol extract (IC50 value of 57 g/mL), which may be related to the particular phytochemical content of both the extracts. Triterpenoids, saponins, steroid hormones with tannins were discovered to be present in the petroleum ether extract, but flavonols are the only chemical present in the ethanol extract. [68]. On the human epithelial laryngeal carcinoma (Hep-2) cell line, the hydrophilic (100% methanol) extract outperformed the lipophilic (1:1, ethyl acetate: hexane) extract in terms of anticancer

activity [69]. The hydrophilic extract's potent active ingredients were mostly ternatins, kaempferol, quercetin, which, as opposed to the lipophilic extract, are crucial for the antiproliferative impact, which is composed of tocopherols, phytosterols, and fatty acids. flower extract with anti-diabetic properties. The aqueous extract significantly decreased the quantity of fructosamine in glycated bovine serum albumin (14.47-36.66%) as well as the generation of fluorescent advanced glycation end products, with the maximum effect occurring at day 28 (49.4% at 1 mg/mL). According to the study, the extract's capacity to scavenge free radicals—which is mostly because it contains the active components kaempferol, delphinidin derivatives, and ternatinanthocyanins—may be what allow it to prevent the production of advanced glycation end products. [70]. These studies collectively suggested that the flavonoid and alkaloids included in the extract (flavonol, glycosides, and anthocyanins) may have hypoglycemic effects via promoting insulin secretion from beta cells or by facilitating the transit of blood sugar from peripheral tissues into the plasma.

10. **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 using an alcohol extraction of Clitoriaternatea leaves in vitro presented superior calcium oxalate crystallisation prevention (72.991.2%) compared with cystone (90.551.27%) [72].

V. CONCLUSION

The edible blue pea flower, also called Clitoria *ternatea*, is significant both aesthetically and therapeutically numerous polyacylated anthocyanins, which are more stable compared to non-acylated anthocyanins, is present in blue pea flowers. It is simpler to employ anthocyanins from blue pea flowers as a blue food colouring agent in acidic food systems because they exhibit a highly vivid and uniform blue colour in acidic medium. 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 location of departure 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 targets for molecules in the body of a person, 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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