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A COMPREHENSIVE EVALUATION OF *CLITORIA TERNATEA* ITS BOTANICAL DESCRIPTION, PHYTOCHEMISTRY, PHARMACOLOGICAL ACTIVITIES, AND TRADITIONAL USES

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Abstract

The plant known as "Butterfly pea" (*Clitoria ternatea* L. (CT)) belongs to the Fabaceae family and has been extensively used in traditional Ayurvedic medicine for various purposes. These include enhancing memory, reducing stress, alleviating anxiety, combating depression and seizures, and soothing the nervous system. The isolated secondary metabolites from *Clitoria ternatea* Linn consist of steroids, anthocyanins, triterpenoids, and flavonol glycosides. The preparations of this substance exhibit a wide range of pharmacological activity, including anti-inflammatory, antifungal, antimicrobial, antipyretic, analgesic, diuretic, local anaesthetic, antidiabetic, insecticidal, and vascular smooth muscle relaxing effects. Scientific research has confirmed the plant's extensive use in traditional Ayurvedic medicine for treating various illnesses, including some that are still relevant today. Recently, there has been significant interest in the medicinal and agricultural applications of *Clitoria ternatea*, a perennial legume usually referred to as butterfly pea. These applications encompass nitrogen fixation in the soil, production of colours and cosmetics, treatment of specific ailments, and even utilisation as an eco-friendly insecticide. Acquire thorough knowledge of the physical characteristics, geographical range, classification, natural environment, development, reproduction, chemical composition, and practical applications of this plant through our interdisciplinary review. Anthocyanins, the chemical constituents accountable for the blue hue of *C. ternatea* flowers, and cyclotides, which are found in all parts of this plant, are especially remarkable. The latter refers to bioactive molecules found in a plant extract that is commercially utilised as an insecticide. These compounds are highly potent insecticidal agents.

Keywords: *Clitoria ternatea*, Phytochemistry, Pharmacological activities, Traditional uses

Introduction

Aromatic and medicinal plants have been known to mankind across all nations and civilizations from ancient times for their therapeutic, religious, cosmetic, nutritional, and aesthetic benefits. These uses have been known for centuries[1]. *Clitoria ternatea* is a plant that belongs to the Fabaceae family as well as the Plantae kingdom. More precisely, it belongs to the phylum Tracheophyta and the class Magnoliopsida[2]. Many people call the perennial climber *Clitoria ternatea* butterfly pea or blue pea flower. Both of these names are common names for the plant. It has the potential to grow to a height of two to three metres[3]. The term is known by different names in different regions: aparajita in Bengali, kajroti in Indian, cunha in Brazilian Portuguese, cunhã, fula criqua in Chinese, bunga biru, tembang telang in Indonesian, bunga telang in Malaysian, clitoria azul in Spanish, dangchan in Thai, chi đậu biếc in Vietnamese, and mavi kelebek sarmaşığı in Turkish[4]. On the other hand, the blue flower pigment has a long history of

use as a culinary colourant in Southeast Asia; but, in the West, it is more commonly planted as an ornamental plant and as a species for revegetation. As a result of its ability to fix nitrogen and its potential to suppress the growth of perennial weeds, this plant is an excellent candidate for use as a green manure or cover crop[5]. The genus *C. ternatea* can be discovered in a wide variety of locations across the globe, such as the Caribbean, Madagascar, South and Central America, the Philippines, and a number of tropical Asian countries. *Clitoria ternatea* is known to have nootropic qualities, which are recognised by practitioners of Ayurveda. The seeds of the plant need to germinate for approximately one to two weeks before it may bloom, which comes to a total of approximately four weeks[6]. The plant flourishes in regions that are either completely exposed to sunlight or partially shaded. There are many different flower colours that may be found on *C. ternatea*, such as white, mauve, light blue, and dark blue. The flowers on each variation are approximately 4-5 centimetres in length (Fig. 1). Myricetin, kaempferol, and quercetin are only some of the flavanol glycosides that are reported to be present in the flowers. Additionally, ternatin anthocyanins are said to be present. It is possible for the elliptic-oblong leaves to range in length from 2.5 to 5.0 centimetres and width from 2.0 to 3.2 centimetres[7]. These leaves are pinnate and include between five and seven leaflets. After being softened, the seed pods, which are flat, linear, and beaked, can be consumed. The length of the seed pods can range anywhere from five to seven centimeters[8]. The seed, which is found in an oval shape, can range in length from 4.5 to 7.0 millimetres and in width from 3 to 4 millimetres. Its colour can be either a dark brown or a yellowish brown. Several thin lateral roots are what distinguish the taproot system from other root systems[9].



Fig 1: *Clitoria ternatea* Leaves and Flower

Scientific classification

| | |
|-------------|-----------------|
| Kingdom | Plantae |
| Subkingdom | Viridiplantae |
| Division | Tracheophyta |
| Subdivision | Spermatophytina |
| Class | Magnoliopsida |
| Superorder | Rosanae |
| Order | Fabales |

| | |
|---------|--------------------|
| Family | Fabaceae |
| Genus | <i>Clitoria</i> L |
| Species | <i>C. ternatea</i> |

Botanical description

One of the distinguishing characteristics of the perennial climber or trailing plant *Clitoria ternatea* is that it has a woody rootstock. There are two to four pairs of imparipinnate leaflets on each leaflet, and there is only one terminal leaflet[10]. While the lower surface of these leaflets is covered in hair, the upper side of these leaflets is largely hairless. Their diameters range from ovate to ellipticoblong, and they can be as large as 6.5 centimetres by 4 centimetres. The plant produces blooms that are either solitary or paired, and they are found in the axillary branches of the plant. The flowers are quite stunning in their vividness and lightness. Typically mucronate at the top, the pod is flattened and is between 6 and 13 centimetres in length; it is linear-oblong in shape. It is possible to have pods that are either hairless or finely pubescent[11].

Material methods

A comprehensive investigation was carried out on the scientific database Pubmed, Scopus, Scielo, International journal, Google scholar and Science Direct utilising the keywords *Clitoria ternatea*, phytochemistry, pharmacological activity, Antioxidant activity, Antifungal activity, Anti microbial activity, Traditional uses.

Phytochemistry

In addition to its usage as a natural food additive and a supposed treatment for a wide variety of illnesses, *C. ternatea* has a lengthy history of application that has been beneficial. Neda et al. reported the nutritional composition of *C. ternatea* flowers, in addition to the phytochemical components that were found throughout the blooms[12]. The moisture content of it is 92.4%, while the percentages of fat, carbohydrates, fibre, and protein are as follows: 2.5% for fat, 2.2% for carbohydrates, 2.1% for fibre, and 0.32% for protein. Potassium (1.25 mg/g), sodium (0.14 mg/g), iron (0.14 mg/g), zinc (0.59 mg/g), and magnesium (2.23 mg/g) were the minerals that were discovered in the flowers in high concentrations[13]. It is the phenolic chemicals that are

present in the plant, particularly those that are found in the flower petals, that are responsible for the beneficial effects. These are just some of the bioactive chemicals that can be found in *C. ternatea*. Other bioactive substances include saponins, alkaloids, glycosides, phenols, steroids, glycosides, resins, and flavonoids[14]. Both the isolation of malonylated flavonol glycosides from flower petals and their subsequent isolation were reported in another piece of research. Several flavanol glycosides of kaempferol, rutin, quercetin, and myricetin are found in a hydrophilic extract of *C. ternatea* flowers, as stated by Mukherjee and Kazuma. Additionally, phenolic components such as ternatin anthocyanins are present in the extract. In addition, a lipophilic extract is comprised of a variety of fatty acids, phytosterols, and tocopherols. These include campesterol, stigmasterol, β -sitosterol, sitostanol, petroselinic acid, linoleic acid, arachidic acid, behenic acid, and phytanic acid inside the extract[15]. There is a paucity of quantitative findings on this subject, despite the fact that previous research has provided a complete description of the phytochemical makeup in terms of their hydrophobicity.

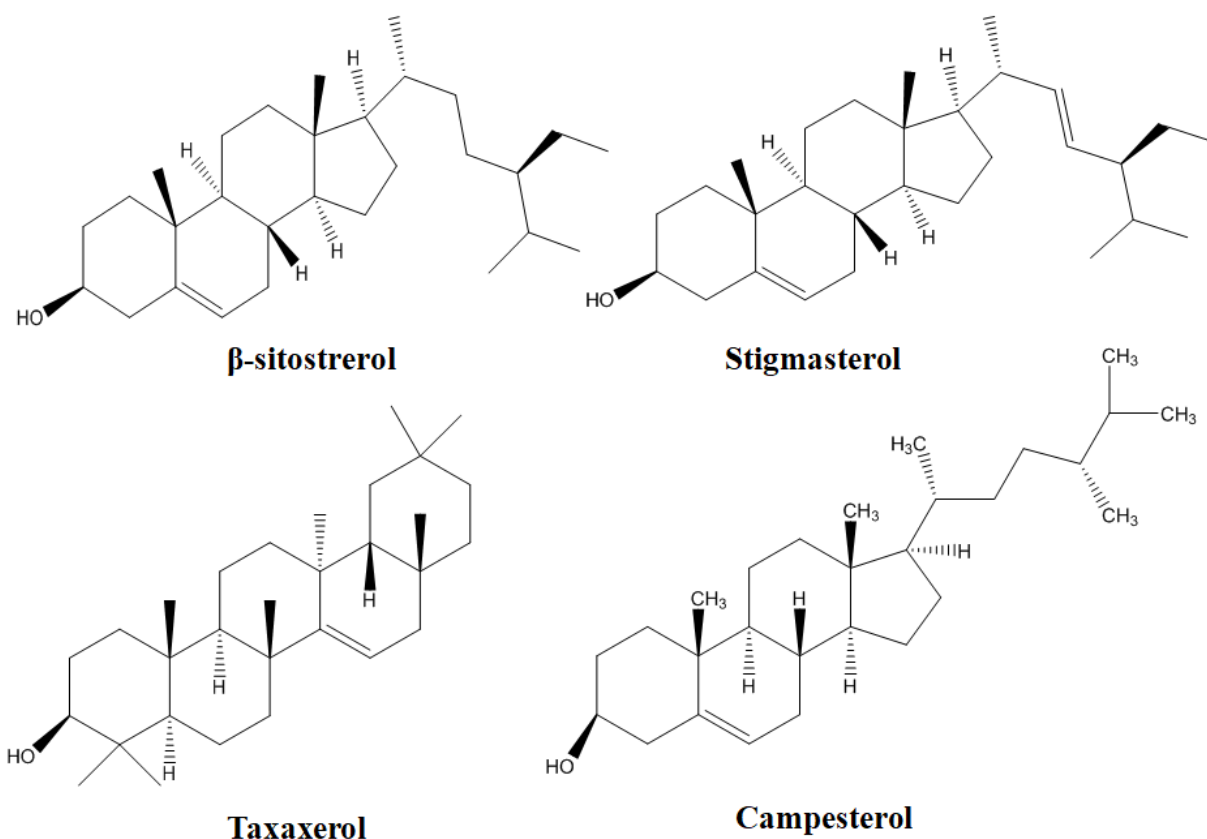


Fig 2: Phytosterols in *C. ternatea* flower

The majority of the phyto-constituents found in the plant are composed of pentacyclic triterpenoids, specifically taraxerone and taraxerol. The ethanol extract of *Clitoria ternatea* contains a number of chemicals that have the potential to act as antioxidants[16]. These components include terpenoid, flavonoid, tannin, and steroid antioxidants. Taraxerol and taraxerone are examples of pentacyclic triterpenoids, which are responsible for the majority of the phytoconstituents found in *Clitoria ternatea* flowers[17]. Ternatins, alkaloids, flavonoids, tannins, carbohydrates, proteins, resins, starch, taraxerol, and taraxerone were discovered through phytochemical analysis of the roots. Taraxerol and taraxerone furthermore were discovered[18].

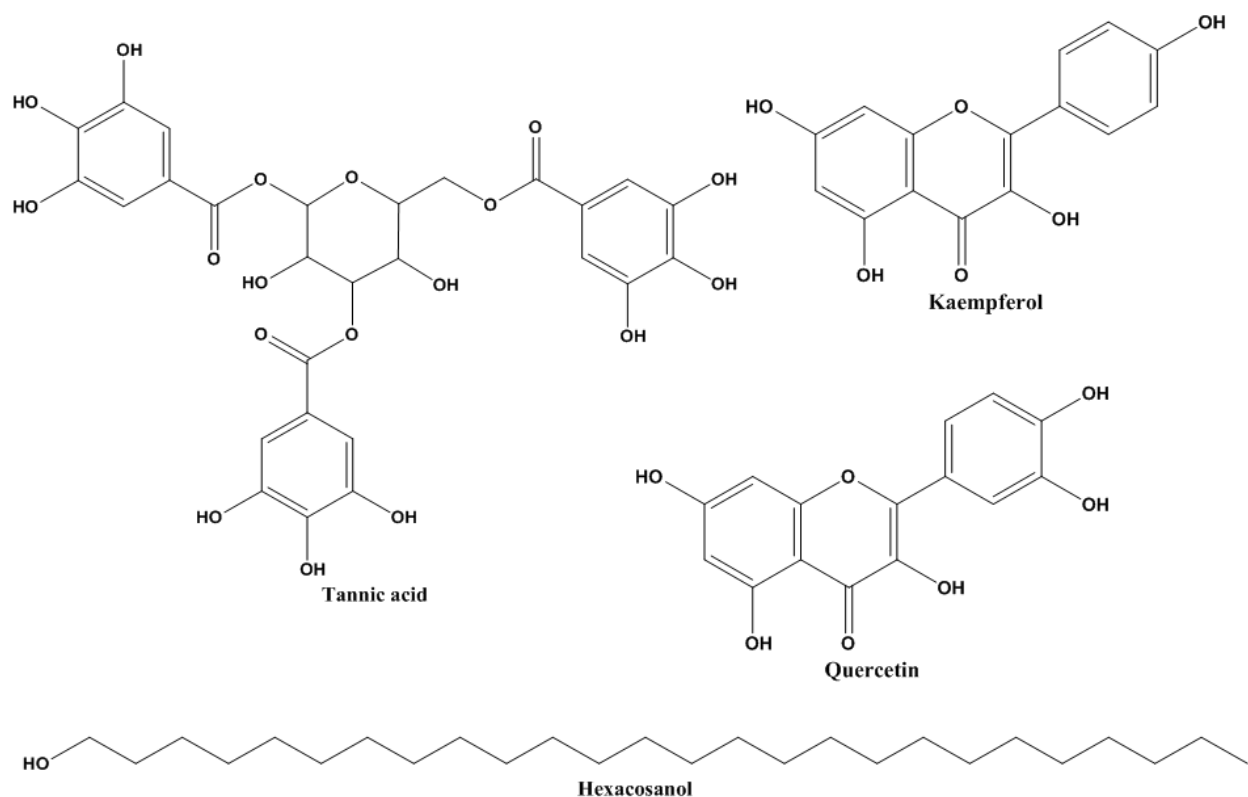


Fig 3: Chemical compounds found in *C. ternatea*

Pharmacological activities

Antioxidant activity

Chemical-based tests were carried out by Jeyaraj et al. using the use of 2,2-diphenyl-1-picrylhydrazyl radical (DPPH) and ferric reducing power (FRP) in order to evaluate the antioxidant activity of the anthocyanin-rich fraction of *C. ternatea* flowers[19]. Through the DPPH experiment, it was determined that the radical scavenging activity of the anthocyanin-rich fraction had an IC₅₀ value of 0.86 ± 0.07 mg/mL[20]. The fraction was shown to be more effective than the crude extracts, as demonstrated by our previous research. The IC₅₀ value for the solvent extract was 1.24 ± 0.05 mg/mL, whereas the water extract had an IC₅₀ value of 1.18 ± 0.07 mg/mL[21]. According to the findings for FRP, the anthocyanin-rich fraction of *C. ternatea* flowers contained 34.5 mg gallic acid equivalent per gramme of extract. This indicates that the extract is more powerful than the crude extracts that were published earlier[22].

According to the results of the DPPH experiment, the IC₅₀ values for the antioxidant activities of *C. ternatea* flowers ranged from 0.08 to 4 mg/ml. Previous research on these qualities has primarily concentrated on extracts composed of solvents or water[23]. Other research indicates that the anthocyanins found in other fruits are more potent than those found in the crude extracts of the fruit in question. One study investigated the antioxidant effects of both crude and anthocyanin-rich mulberry extract[24]. The researchers looked at both types of extract. When compared to the crude extract, the anthocyanin-rich extract was found to have a higher level of antioxidant activity, as determined by the DPPH test. The anthocyanin-rich blackberry extract performed better than the crude extract in the ORAC assay for antioxidant activity, according to the findings of another study that found a similar pattern[25]. Comparing the anthocyanins of mulberry fruit, which are derived from cyanidin derivatives with aglycone functional groups, to those of blackberry fruit, which are derived from delphinidin derivatives in the triacylated form, these investigations discovered that there are structural differences between the two types of anthocyanins[26]. The cyanidin-3-glucoside component accounts for the vast majority of the anthocyanins found in blackberry fruit. Previous studies have shown that the antioxidant properties of *C. ternatea* flowers are due to the presence of a number of flavonols and anthocyanins in the blooms[27]. Using the chemical antioxidant test is the method that is considered to be the standard for assessing antioxidant activity. However, these tests have no reference whatsoever to the biological systems that exist in the real world. In the majority of the research that has been conducted on the antioxidant activity of *C. ternatea* flower extracts up until this point, chemical assays have served as the foundation. For the purpose of this investigation, a cellular antioxidant activity (CAA) assay was utilised because it has the capability to overcome issues with bioavailability, metabolism, and absorption that are encountered when chemical antioxidant assays are conducted. Using the MTA assay, the cytotoxicity of the anthocyanin-rich fraction (39.1-2500 µg/mL) was evaluated on RAW264.7 cells at a time interval of 24 hours. This was done in order to identify the non-toxic concentration that should be utilised in the CAA assay technique. Performing this action was done in order to guarantee that the concentration range that was utilised and the antioxidant activity that was found were not the result of cell death or toxicity[28].

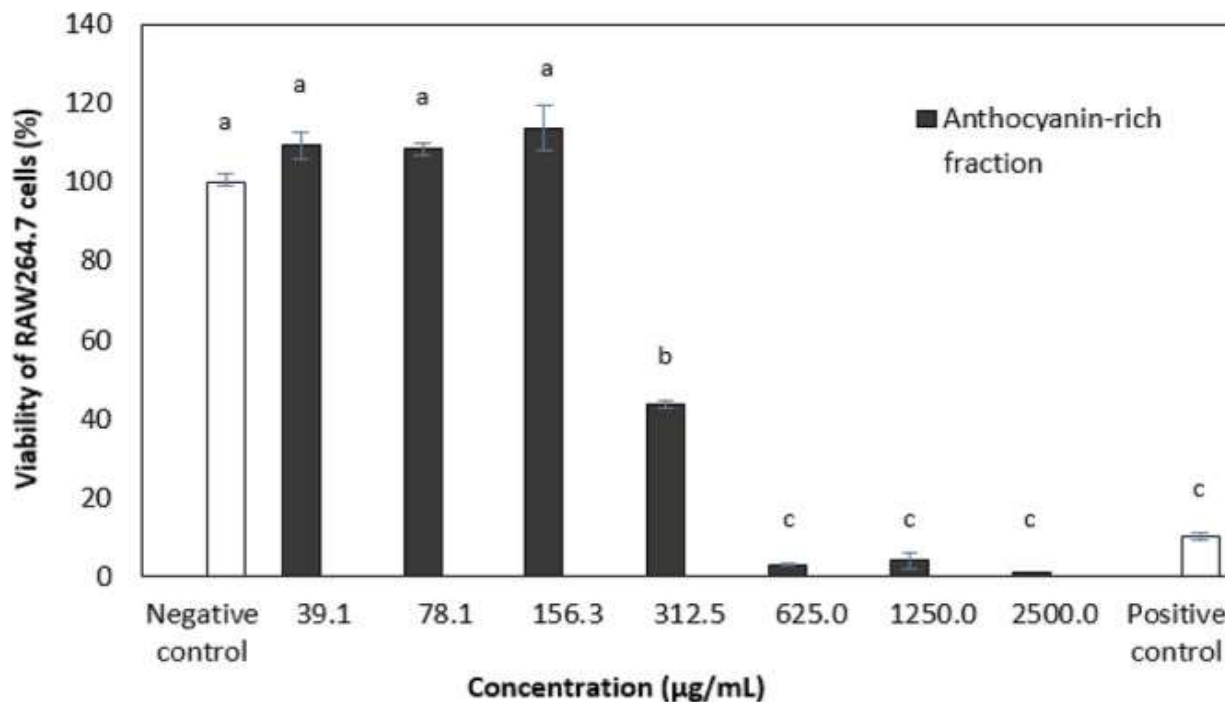


Fig 4: The viability of RAW264.7 cells after 24 hours of treatment with various concentrations ($\mu\text{g/mL}$) of the anthocyanin-rich fraction of *C. ternatea* flowers. The values are the means with standard deviations, for $n = 3$. In terms of cell viability, values denoted by various letters are statistically different ($p < 0.05$). The cells that were not treated served as the negative control, whereas the cells that were lysed with 1% Triton X-100 served as the positive control. (Used with permission from Jeyaraj, E. J., Lim, Y. Y., & Choo, W. S. (2022). Antioxidant, cytotoxic, and antibacterial activities of *Clitoria ternatea* flower extracts and anthocyanin-rich fraction. *Scientific reports*, 12(1), 14890. <https://doi.org/10.1038/s41598-022-19146-z>)

Antifungal activity

On potato dextrose agar (PDA) plates, the antifungal activity of floral extracts from *C. ternatea* was evaluated by the use of the well diffusion method. The inoculum of *C. hoffmannii* was cultivated in a PDB medium for forty-eight hours at a temperature of twenty-seven degrees Celsius and a rotational speed of one hundred revolutions per minute[29]. The density of the yeast cell culture was adjusted to 0.5 McFarland units by means of a spectrophotometer manufactured in Japan by Jasco and referred to as the V-770. A uniform distribution of the inoculum that had been prepared was carried out across the PDA plates. To mix the solvent-free plant extracts with DMSO (provided by SD Fine Chemicals Ltd., Mumbai, India), concentrations

of 1,000, 1,500, 2000, and 2,500 micrograms per millilitre were taken into consideration. For the purpose of accommodating the addition of the extracts, wells were created in the agar platters. Fluconazole, which was manufactured by HiMedia Laboratories in Mumbai, India, was used as a positive control, and DMSO was utilised as a negative control within our experiment. The diameter of the inhibitory zone was measured in millimetres after it had been incubated for forty-eight hours at thirteen degrees Celsius[30]. There is a long tradition of using the blue blooms of *C. ternatea* as an eye cure, and researchers are actively investigating the possibility that these flowers contain medicinal characteristics. *C. ternatea* flower extracts were found to have a substantial inhibitory effect on the clinical isolate of the fungus *Candida hoffmannii*, according to the findings of the study[31]. At the lowest concentration, the inhibitory effect of CFEA was found to be the most strong. There were no inhibitory effects observed in the water extract; however, the inhibitory effects observed in the petroleum ether and acetone extracts were significantly reduced. There was a variation in the average inhibition zone of the active extracts, which ranged from 9.83 ± 0.28 to 23 ± 1.0 mm. The CFEA extract had the highest antifungal effectiveness, with a range of 11.50 ± 0.50 to 23 ± 1.0 mm, as shown in Figure 5[32]. When the DMSO was used as the negative control, there were no inhibitory effects that were identified. On the contrary, when fluconazole was used as the positive control, an inhibitory zone of 23 ± 0.5 mm was seen[33]. Through the utilisation of MIC and MFC values of 0.5 and 1 mg mL⁻¹, respectively, the findings indicate that the CFEA extract exhibits greater efficacy in combating *C. hoffmannii* in comparison to the other extracts present[34].

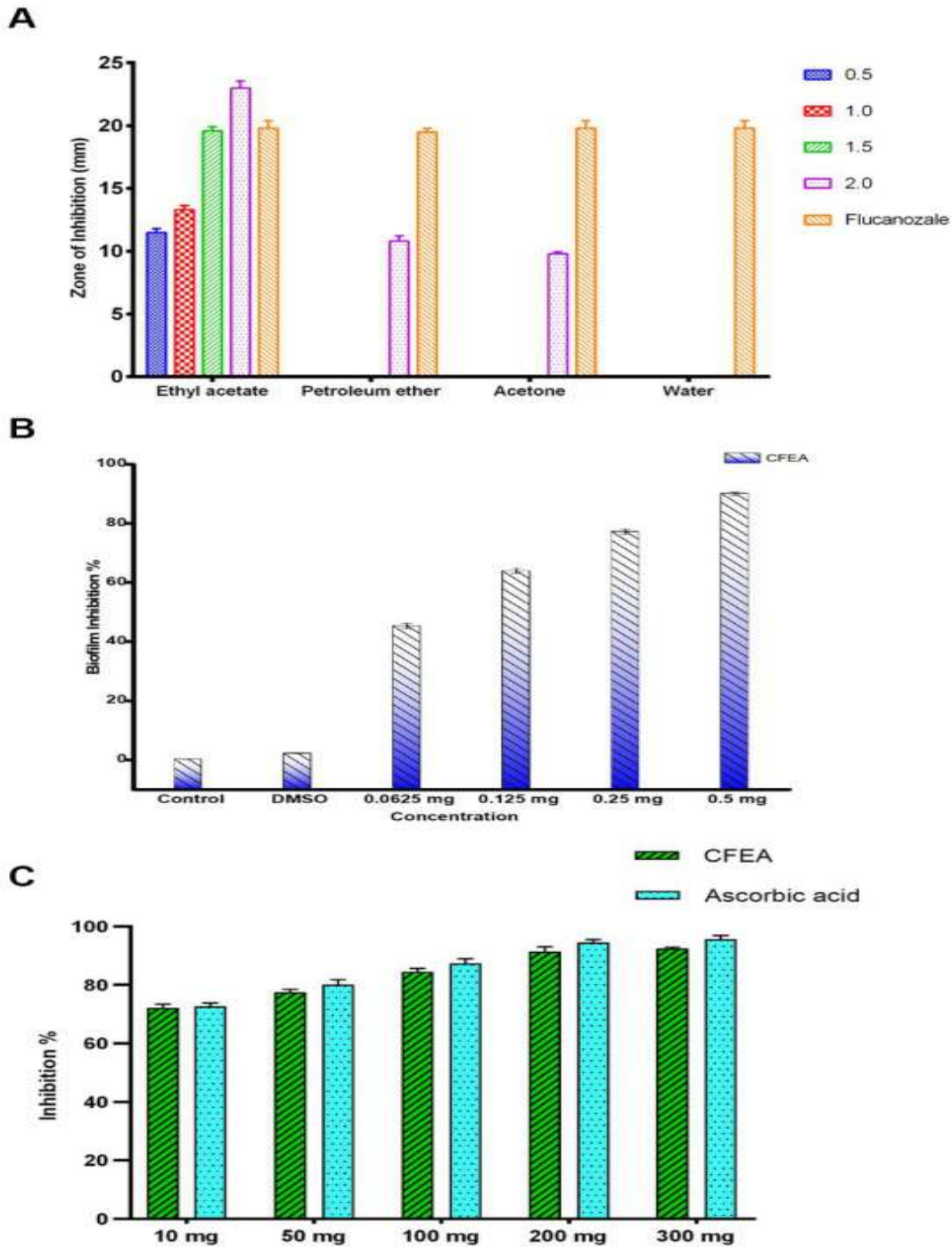


Fig 5: At different doses, the graph shows (A) the antifungal activity of flower extracts of *C. ternatea* L. against *C. hoffmannii*. The percentage of antibiofilm inhibition of CFEA against *C. hoffmannii* is shown in (B). (C) Antioxidant potential of CFEA at different doses and comparison with reference ascorbic acid (Used with permission from Yolín Angel, P. A. S. R., Jeyakumar, P., Jasmin Suriya, A. R., Sheena, A., Karuppiyah, P., Periyasami, G., Stalin, A., &

Murugan, K. (2024). Topical antifungal keratitis therapeutic potential of *Clitoria ternatea* Linn. flower extract: phytochemical profiling, *in silico* modelling, and *in vitro* biological activity assessment. *Frontiers in microbiology*, 15, 1343988. <https://doi.org/10.3389/fmicb.2024.1343988>

Anti microbial activity

Antimicrobial medications have been shown to lessen the incidence of infectious diseases in both humans and other animals. It is possible that medicinal plants contain a naturally occurring antibacterial agent. As a result of the fact that *Clitoria ternatea* is both harmless and beneficial to human beings, the potential research and development resources might be put to good use by discovering new ways to attack bacteria[35]. This bean has the potential to be an effective antibacterial agent due to the fact that its crude extract was able to kill germs more effectively than the traditionally used antibiotic streptomycin. For the purpose of determining the antibacterial activity of *C. ternatea*, disc diffusion testing was performed using a variety of extractions, such as methanol, petroleum ether, and ethyl acetate. The leaves of *C. ternatea* were extracted with methanol and tested for their ability to inhibit the growth of various bacteria. These bacteria included *Bacillus cereus* (with a length of 1.2 ± 0.8 cm), *Proteus vulgaris* (with a length of 0.1 ± 0.0 cm), *Salmonella typhi* (with a length of 0.1 ± 0.0 cm), *Staphylococcus aureus* (with a length of 0.2 ± 0.1 cm), and *Klebsiella pneumoniae* (with a length of 0.8 ± 0.2 cm)[36]. Through the use of the disc diffusion method, it was found that methanol extracts of *C. ternatea* leaves exhibited much more effectiveness as inhibitors. It should come as no surprise that the methanol extracts demonstrated the greatest potential for antibacterial activity that was seen. The scope of antibiotics and antimicrobial chemotherapy has been broadened to include new chemicals that are derived from plants[37]. There have been other references that have mentioned the antibacterial activities of the leaves of *C. ternatea*. The phytochemical properties and active chemical components of *C. ternatea* were the focus of one of the studies that were conducted[38]. For the purpose of gaining an understanding of the therapeutic properties of medicinal plants, it is essential to carry out research on phytochemicals and biological screening. The phytoconstituents that are detected in *C. ternatea* are characterised by their high levels of total phenols (245.14 ± 6.97 mg TAE \cdot g⁻¹), tannins (78.75 ± 2.09 mg TAE \cdot g⁻¹), and flavonoids (0.48 ± 0.96 mg RE \cdot g⁻¹), which are the most numerous among the phytoconstituents. Because

of its twin activities as a plant stress regulator and a biological response modulator in humans, *C. ternatea* possesses therapeutic characteristics that are based on these dual roles. The antifungal effects of the ethanolic leaf extract of *C. ternatea* were investigated in another study[39]. The results showed that the extract can protect *Pisum sativum* seed from *Fusarium oxysporum* invasion. The fact that *C. ternatea* can be utilised in the medical field as an antifungal agent is demonstrated by this. One further intriguing discovery is that the ethanol-based extract of the leaves of *C. ternatea* has the potential to be effective in treating cryptococcosis and candidiasis. Researchers in Southern India have identified and catalogued all of these species in order to investigate the antiviral properties of medicinal plants, including *C. ternatea*, which are found in the region. This tropical Asian flower was shown to offer extraordinary antiviral activity, as demonstrated by tests conducted with anti-coronavirus (MCoV) extracts using a virucidal approach[40].

Traditional uses

In addition to being referred to as tisane, butterfly-pea flower tea is a herbal beverage that does not contain caffeine. It is made by brewing a combination of dried lemongrass and the leaves of the *Clitoria ternatea* plant. Butterfly pea flower tea not only retains many of the curative properties of the *Clitoria ternatea* plant, but it also extracts the plant's renownedly deep blue petals, which have been utilised as a dye for many years. When acidic chemicals are added to tea, the colour of the tea changes; for instance, if you add lemon juice to the tea, the beverage will undergo a purple transformation[41]. This is one of the characteristics of tea. As an additional point of interest, this plant has a long history of application in Chinese medicine for the treatment of conditions that are associated with the reproductive system. "Aparajita" is the Bengali name for the herb *Clitoria ternatea*, which is used in Ayurvedic medicine[42]. All of the plant's components, including the stems, roots, and leaves, have potential applications in the medical field. In traditional Ayurvedic medicine, it has been used for millennia as a nootropic, stress reliever, anxiolytic, antidepressant, anticonvulsant, sedative, tranquillizer, and memory booster. Its lengthy history of use extends back to the beginning of the medical practice. It is also prevalent in cases of disorders that affect the nervous system. The root was used to treat a variety of conditions, including ascetics, swollen abdominal viscera, sore throats, and skin diseases. In addition, they were prescribed as a purgative; however, it was recommended that they not be

used in this capacity because they cause writhing and sensitivity. Root that was mixed with honey and ghee was administered to youngsters as a general tonic in order to enhance their cerebral capabilities, physical strength, and complexion qualities[43]. Roots were also used to treat conditions such as epilepsy and insanity. For a considerable amount of time, the seeds and leaves of the plant were thought to be a cure-all for memory degradation and cognitive impairment. Floral juice was used to create an antidote for snake bite that was effective. In the past, people would crush seeds and then combine them with either cold or boiling water in order to treat urinary tract infections and sore joints.

Conclusion

In conclusion, the Butterfly pea, also known as *Clitoria ternatea*, has been utilised in the medical field for a considerable amount of time and possesses a significant amount of potential for the future. The wild and valuable *Clitoria ternatea* is a shrub that has a variety of applications in the medical field. In addition to a few specific applications in the medical field, it has a wide range of traditional applications. In addition to treating cancer, it is also effective in treating neurological disorders, nephrology issues, hyperglycemia, urinary disorders, goitre, respiratory disorders, and other conditions that cannot be cured. The following is a compilation of data that will serve as a roadmap for future research into the pharmacological activities of this plant as well as the active chemical that it contains.

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