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Review

The Potential for the Implementation of Pea Flower (*Clitoria ternatea*) Health Properties in Food Matrix

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Abstract: *Clitoria ternatea* is a revered flower and plant in botanical science. While its health benefits are only recently gaining popularity, the plant itself has been the recipient of many traditional and indigenous medicines, including that of Ayurvedic medicine in South Asia. The peculiar property of this flower is its ability to change color depending on its pH. This review article encompasses the literature surrounding this plant and its valuable flower and attempts to cover all aspects of its benefits in the food matrix, including its existing applications. It also aims to look at the flower from a holistic perspective and imagine it as a source of future food.

Keywords: *Clitoria ternatea*; antioxidants; Ayurvedic medicine; functional food; pro health

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1. Introduction

The *Clitoria ternatea* (butterfly pea) has gained a lot of attention due to its role in traditional medicine, food coloring, cosmetics, fodder, and as a source of an environmentally friendly insecticide, among other agricultural and medical applications [1]. There are various names for this perennial leguminous plant in the Fabaceae family, including Blue Bell Vine, Asian Pigeon Wings, Cordofan Pea, Blue Pea, and Darwin Pea. It is also known as "Shankapushpi" (conch flower) in indigenous states, as well as "Aparajit" (Hindi), "Aparajita" (Bengali), and "Kakkattan" (Tamil) [2,3]. The young shoots, leaves, flowers, and delicate pods are used as vegetables in South India and the Philippines, while in Malaysia, the leaves are used to color food green and the flowering to color rice cakes bright blue [4].

While its origins are debatable, it is now native to parts of India, South America, Southern and Eastern Africa, Madagascar, and the Western Indian Ocean. It has also become a good feeding source for the hot and semi-arid North-Eastern Brazil due to its adaptability and persistence under drought circumstances, as well as its capacity for regrowth quickly after the rainy season begins, aside from its good palatability and nutritional content [1].

This paper highlights the basic information about this flower and how it has been regarded in several indigenous cultures, including the nature-based healing of Indian Ayurveda and that of South America, which was carried down from the early civilizations. This paper compiles a list of functional attributes of the pea flower and the bioactive compounds which are the reason behind it. It also compiles a comprehensive list of tested and commercially existing products.

2. Botanical Characteristics of *Clitoria ternatea*

In terms of its botanical features, this plant could be characterized as a perennial, strong, twining, climbing, tropical plant with pinnate leaves that grows in the summer. It has five to seven elliptical, three to five cm long leaves with a dorsal structure visible in the cross-section. At maturity, the flowers are either single or paired, and the fruits are flat, linear pods that are lightly pubescent, and each one contains eight to ten dark-colored seeds [5]. The root is a taproot that has numerous thin lateral roots and a few branches.

In addition to calcareous soil and heavy cracking soil, such as that found in Australia, it flourishes in a wide range of soil types with pH values between 5.5 and 8.9 [6,7].

3. Bioactive Compounds of *Clitoria ternatea*

C. ternatea is popular for the number of bioactive compounds present in the flower. Over time, several studies have tried to extract these from the flower itself and its food products. Kazuma and colleagues [8] studied the concentrations of these bioactive compounds, such as anthocyanins, flavonoids, and fatty acids, across the different colored varieties of this flower (Table 1).

Table 1. Bioactive compounds found in *Clitoria ternatea* flowers.

Name of Compound	Double Blue Flowers [8] (pmol/mg fw *)	Blue Flowers (wild) [8] (pmol/mg fw)	Mauve Flowers [8] (pmol/mg fw)	White Flowers Tissue [8] (pmol/mg fw)	Unknown Tissue [9] (mg g^{-1} fw)
Anthocyanins					
Delphinidin3-(2″-rhamnosyl-6″-malonyl)glucoside)	n.d. **	n.d.	142.7 ± 23.4	n.d.	
Delphinidin3-(6″-malonyl)glucoside	n.d.	n.d.	1691.6 ± 704.6	n.d.	
Delphinidin3-neohesperidoside	n.d.	n.d.	5.2 ± 2.4	n.d.	
Delphinidin3-glucoside	n.d.	n.d.	51.5 ± 24.5	n.d.	
Delphinidin derivative					0.28 ± 0.01
Delphinidin derivative					2.13 ± 0.16
TernatinA1	425.4 ± 87.7	289.7 ± 39.5	n.d.	n.d.	
TernatinA2	539.6 ± 124.2	416.8 ± 6.3	n.d.	n.d.	
TernatinA3	100.2 ± 25.6	311.3 ± 39.3	n.d.	n.d.	
TernatinB1	1544.5 ± 281.0	769.5 ± 27.2	n.d.	n.d.	
TernatinB2	999.4 ± 254.4	928.8 ± 51.7	n.d.	n.d.	
TernatinB3	444.8 ± 105.6	295.5 ± 16.4	n.d.	n.d.	
TernatinB4	111.9 ± 36.3	302.1 ± 46.3	n.d.	n.d.	
TernatinC1	160.7 ± 65.0	157.3 ± 9.2	n.d.	n.d.	
TernatinC2	81.7 ± 29.6	71.6 ± 4.1	n.d.	n.d.	
TernatinC3	14.4 ± 25.2	104.4 ± 4.3	n.d.	n.d.	
TernatinC4	41.4 ± 16.7	186.0 ± 11.1	n.d.	n.d.	
TernatinC5	16.5 ± 13.5	71.1 ± 24.3	n.d.	n.d.	
TernatinD1	1630.6 ± 338.8	750.7 ± 31.3	n.d.	n.d.	
TernatinD2	622.7 ± 172.2	540.0 ± 65.2	n.d.	n.d.	
TernatinD3	127.7 ± 41.4	206.6 ± 27.5	n.d.	n.d.	
Flavonol glycosides					
Kaempferol3-(2G-rhamnosylrutinoside)	1738.2 ± 280.3	3571.7 ± 61.0	2418.8 ± 181.3	1342.1 ± 123.3	
Kaempferol3-neohesperidoside	6454.9 ± 1125.0	8225.1 ± 386.6	8547.4 ± 811.5	4218.4 ± 464.7	
Kaempferol3-(2″-rhamnosyl-6″-malonyl)glucoside	567.3 ± 93.6	841.5 ± 17.9	712.4 ± 66.6	417.8 ± 46.2	
Kaempferol3-rutinoside	23.5 ± 9.6	72.4 ± 5.0	42.8 ± 1.5	81.5 ± 19.0	
Kaempferol3-glucoside	n.q. ***	n.q.	86.1 ± 2.1	71.0 ± 5.8	

Table 1. *Cont.*

Name of Compound	Double Blue Flowers [8] (pmol/mg fw *)	Blue Flowers (wild) [8] (pmol/mg fw)	Mauve Flowers [8] (pmol/mg fw)	White Flowers Tissue [8] (pmol/mg fw)	Unknown Tissue [9] (mg g^{-1} fw)
Quercetin3-(2G″-rhamnosylrutinoside)	388.3 ± 61.0	501.0 ± 13.0	289.2 ± 15.4	291.6 ± 30.5	
Quercetin3-neohesperidoside	1012.7 ± 199.9	631.0 ± 37.3	764.3 ± 46.6	613.7 ± 63.4	
Quercetin3-(2″-rhamnosyl-6″-malonyl)glucoside	n.q.	n.q.	n.q.	n.q.	
Quercetin3-rutinoside	231.9 ± 63.4	449.0 ± 78.8	94.2 ± 8.2	321.2 ± 105.4	
Quercetin3-glucoside	249.9 ± 119.2	335.9 ± 66.0	55.2 ± 7.1	325.3 ± 147.2	
Myricetin3-(2″-rhamnosylrutinoside)	56.8 ± 10.0	37.4 ± 7.1	28.1 ± 2.3	246.0 ± 26.2	
Myricetin3-neohesperidoside	n.d.	n.d.	41.5 ± 4.0	328.0 ± 42.8	
Myricetin3-(2″-rhamnosyl-6″-malonyl)glucoside	n.d.	n.d.	n.d.	38.3 ± 4.1	
Myricetin3-rutinoside	n.d.	n.d.	n.d.	384.5 ± 45.3	
Myricetin3-glucoside	n.d.	n.d.	n.d.	391.3 ± 56.5	
The total amount (nmol/mg fw petal)					
Flavonoids	17.59 ± 3.30	20.07 ± 0.55	14.97 ± 0.54	9.07 ± 0.83	
Anthocyanins	6.86 ± 1.61	5.40 ± 0.23	1.89 ± 0.75	n.d.	
Flavonol glycosides	10.72 ± 1.69	14.6 ± 60.33	13.08 ± 1.13	9.07 ± 0.83	
Kaempferol glycosides	8.78 ± 1.49	12.71 ± 0.46	11.81 ± 1.06	6.13 ± 0.65	
Quercetin glycosides	1.88 ± 0.26	1.92 ± 0.12	1.20 ± 0.07	1.55 ± 0.28	
Myricetin glycosides	0.06 ± 0.01	0.04 ± 0.01	0.07 ± 0.01	1.39 ± 0.17	
Fatty acid					
Palmitic acid					2.13 ± 0.18
Stearic acid					1.99 ± 0.16
Petroselinic acid					1.01 ± 0.04
Linoleic acid					4.72 ± 0.51
Arachidic acid					0.36 ± 0.01
Behenic acid					0.30 ± 0.03
Phytanic acid					0.81 ± 0.06
Phytosterols					
Campesterol					1.24 ± 0.02
Stigmasterol					6.70 ± 0.83
β-Sitosterol					6.77 ± 0.19
Sitostanol					1.20 ± 0.03
Tocols					
α-tocopherol					0.20 ± 0.01
γ-tocopherol					0.24 ± 0.02
Phenolic acid					
Ellagic acid					0.21 ± 0.01

* fw—Fresh weight; ** n.d.—Not detected; *** n.q.—Not quantified because it overlapped with other peaks.

In the same study, it was confirmed that the white variety of *C. ternatea* flowers did not produce anthocyanins. They also discovered a unique property of the mauve *C. ternatea* flowers, which was the accumulation of delphinidins lacking the 3′ and 5′ (polyacrylated) glucosyl group. Meanwhile, the research by Shen et al. [9], which was carried out only for the blue flower variety, speaks about the identification of two delphinidin derivatives and cyanidin-3-sophoroside, which they concluded was responsible for the blue color of the petals. They also found that kaempferol 3-neohesperidoside, quercetin 3-(2G-rhamnosylrutinoside), and rutin were the majorly present flavonol glycoside compounds in the petals. There was also a phenolic acid identified in the petals which is ellagic acid.

4. Medicinal Effects of *Clitoria ternatea*

According to the European Commission, functional food can be defined as foods that are related to either an enhanced state of health and well-being or a decreased risk of disease because they have positive impacts on one or more target functions in the body that go beyond conventional nutritional benefits. It fits into a typical dietary pattern and is not a dietary supplement in the form of a pill or capsule [10].

Natural and commercially processed foods that, when regularly consumed in a varied diet in the right amounts, offer potential health advantages beyond those of basic nutrition, are referred to as functional foods. They bridge the conventional gap between food and medicine [11]. Recent studies showed that functional foods have the ability to both prevent and treat disease [12]. When functional foods are ingested on a regular basis, over time they help strengthen the immune system, making a person better able to resist and treat viral and chronic diseases [13]. In terms of pharmacological perspectives, its activities include antimicrobial, antipyretic, anti-inflammatory, analgesic, diuretic, local anesthetic, antidiabetic, and insecticidal activities [14].

4.1. Anti-Arthritic and Anti-Inflammatory Potential

According to Ranaweera et al. [15], a well-known in vitro bioassay model to assess the anti-rheumatoid arthritic potential of an aqueous root extracted from the *C. ternatea*, through the inhibition of heat denaturation of the albumin protein, claimed to act as an index of anti-arthritic activity. In this study, the root extract of the *C. ternatea* plant was checked against a fresh hen's egg albumin, in which the results stated that the extract inhibited the denaturation of protein, which is one of the leading causes of rheumatoid arthritis. While these results were dose-dependent, it was summarized that this was the activity of the interaction of polyphenols and flavonoids with the aliphatic region around the lysine residue around the albumin protein. This study was a significant breakthrough as it showed that *C. ternatea* inhibited antirheumatic arthritis for the first time [15]. Meanwhile, in a study from 2021 [12], carrageenan and histamine-induced paw edema were used to test the EECT's (ethanolic extract of *C. ternatea*) anti-inflammatory effectiveness in which Wistar rats were orally administered the dry, powdered *C. ternatea* dissolved in distilled water. The results were that in both the carrageenan and histamine-induced inflammation, EECT revealed a significant reduction in the mean paw edema volume. The reduction of histamine-induced inflammation could be attributed to quercetin, which inhibits allergic reactions to histamine. In the same study, the anti-arthritic effect of EECT was determined by systematically scoring arthritis symptoms and by measuring paw edema. It was observed that the radiological results showed a significant joint space reduction (intertarsal joints) which indicated cartilage degeneration, bone erosion, soft tissue swelling, and joint deformation in the arthritic control group, whereas the standard and extract-treated groups showed no visible sign of joint deformation. Taraxerol, taraxerone, rutin, quercetin, delphinidin, kaemferol, and malvidin were terpenoids, flavonoids, and triterpenoids that are said to have contributed to it [12,16].

4.2. Anti-Asthmatic Properties

Clitoria ternatea has been used to treat severe bronchitis and asthma in traditional indigenous medicine. According to one research, an alcoholic extract of *C. ternatea* (400 mg/kg, p.o.) also protected Wister rats from histamine-induced bronchospasm. In this study, a suspension of *C. ternatea* extract was made by 1gm of extract in 10 mL of 2% acacia solution and fed to the variable group of rats, while the control group received only histamine (0.2% aerosol). They concluded that the *C. ternatea* extract drastically inhibited the bronchoconstriction (histamine-induced) of the Wistar rats, indicating its H1 receptor antagonistic activity. They attributed this activity to the presence of flavonoids, steroidal nuclei (triterpenoids), and various saponin glycosides [17].

4.3. Analgesic Effects

In one study, the use of 200 and 400 mg/kg of methanolic leaf extract of *C. ternatea* on mice resulted in pain reduction, as measured by the acetic acid-induced writhing test. The rats were orally administered the extract. While this was a singular piece of research, due to its result, it can be assumed that *C. tTernatea* also has analgesic properties [18]. In another study by Bhatia et al. [19] on rats, the leaves were extracted in either ethanol or petroleum ether. It was administered orally in different doses (100 mg/kg, 200 mg/kg, and 400 mg/kg) in the form of a suspension. The model used for this experiment was the tail flick method. Results showed that both the ethanol and petroleum ether extract showed the same type of effect, but the ethanol extract showed a long-lasting effect for up to 2 h.

4.4. Anti-Pyretic Effect

In one early study by Devi et al. [20], it was found that all doses of *C. ternatea* methanolic root extract effectively decreased the body temperature of rats. The rats were subjected to yeast-induced pyrexia and were orally given the extract. The result was that the extract, at doses of 200, 300, and 400 mg/kg body weight, produced a significant reduction in normal body temperature and yeast-provoked elevated temperature in a dose-dependent manner. The effect remained for up to 5 h after the drug had been administered. It was attributed to the flavonoids present in the plant and the antipyretic activity was compared to that of paracetamol, a common antipyretic drug [18].

In another significant study, the antipyretic activities of ethanol and acetone extracts of the leaves were studied using albino rats. In this model, it was found that the antipyretic activity for both types of extracts was higher than the standard drug paracetamol [21].

4.5. Anti-Diabetic and Hypolipidemic Activity

In a study by Kavitha [22], Wistar rats that were given 400 mg of *C. ternatea* ethanolic leaf extract orally once a day for 28 days had considerably lower blood sugar, insulin, glycosylated hemoglobin, urea, and creatinine levels than the diabetic control group. Additionally, the treated rats had lower levels of the liver enzymes (serum glutamate oxalate transaminase, serum glutamate pyruvate transaminase, lactate dehydrogenase, and alkaline phosphatase) than the diabetic control rats and were similar to the normal control rats. The effects of the *C. ternatea* extracts on the human glycaemic response and antioxidant capability were tested in another small-scale clinical research involving 15 healthy males. In this experiment, either 1 or 2 g of *C. ternatea* extract were consumed along with 50 g of sucrose, and the ensuing plasma glucose and insulin levels were controlled. Additionally, after ingesting the extract, the patients' postprandial plasma antioxidant capabilities were increased [1]. The earliest studies for testing the anti-diabetes properties of this flower in rats correlate to research by Sharma and Majumdar in 1990. It was observed that the suppression of the β-galactosidase and α-glucosidase activities in rats (fed ethanol extracts of flowers for 3 weeks) considerably reduced serum sugar levels in experimentally induced diabetes. The overall conclusion of these results for the above studies was attributed to the presence of rich flavonoids, anthocyanins, and alkaloid content in the extract [23].

C. ternatea's hypolipidemic activity was tested in rats that had been experimentally developed with hyperlipidemia in yet another study by Verma et al. [24]. The study used rat models of poloxamer 407-induced, hyperlipidemia and diet-induced hyperlipidemia. The hydroalcoholic extracts of *C. ternatea*'s roots and seeds reduced serum total cholesterol, triglycerides, very low-density lipoprotein (VLDL), and low-density lipoprotein (LDL) cholesterol levels significantly when given orally. This correlated directly with the insulin levels in the body due to hyperglycemia. It was attributed to the polyphenol and flavonoid composition in the plant.

4.6. Wound Healing and Blood Platelet Aggregation Inhibition

Clitoria ternatea's seed and root extracts significantly enhanced wound healing in all mice, whether given orally via gavage or applied topically as an ointment (in an experiment by Solanki and Jain in 2012). These results are similar to those of "cotrimoxazole" ointment. The flavonol glycoside in the seed extract and the phenolic chemicals in plants were summarized as responsible for changing the inflammatory and immunological components of healing [18]. Blood platelet aggregation inhibition is one of the key benefits of this flower, in that the Ternatin D1 present in *C. ternatea* petals showed blood platelet aggregation inhibition (in which collagen and adenosine diphosphate induced platelet aggregation were both inhibited significantly for in vitro rabbit platelets [7]).

4.7. Anti-Tumor Activity

As a part of very limited research, Shivprakash et al. [25] examined cell apoptosis activation with a methanolic extract of the flower, in which the cytotoxic activity was checked with the MTT Cell Viability Assay, light microscopy, DNA fragmentation, and activation of the caspase-3 enzyme, which were used to assess the onset of cell death/apoptosis. The results were that the methanolic extract from the *C. ternatea* was found to be cytotoxic against several cancer cell lines, in which the most effective action was against MCF-7 breast cancer cells, with an IC50 of 27.2 2.6 g/mL. The apoptotic morphology was verified under the light microscope which showed that MCF-7 cells, treated with various methanolic extracts of *C. ternatea* doses, inhibited proliferation and induced apoptosis as evidenced by DNA fragmentation and caspase-3 enzyme activation. While the exact bioactive component for this effect was not recognized, the authors mainly attributed it to polyphenols, including flavonoids, which also exhibit strong antioxidant activity.

4.8. Neuro and Cognitive Enhancing Activity

Numerous studies have found that supplying *C. ternatea* extracts to experimental animals improved their nootropic ability. Notable studies include those of Rai et al. [26], wherein the memory retention and spatial learning skills of 7-day-old newborn rats, orally dosed with 3000 mg/kg of aqueous *C. ternatea* root extract, improved 48 h and 30 days after treatment. Another significant study concluded that electroshock-induced amnesia was improved in rats given ethanolic extracts produced from *C. ternatea* roots or aerial tissues, compared to the controls. The electroshock-induced amnesia model, which causes retrograde amnesia and interferes with memory consolidation, while concurrently reducing brain acetylcholine levels, was used in the current investigation. Step-down latency and the Ach content of the brains of the control rats were both considerably reduced by the electroshock therapy in the current investigation [27]. In another study by Raghu et al. [28], rats were fed jaggery and mashed *C. ternatea* in a ratio of 1:1 as "medhya rasayana" (a therapeutic procedure or preparation, that, if consumed regularly, will boost memory, intellect, and immunity [4]), and it was found that they showed reduced brain autophagy. Genes involved in autophagy regulation, nucleotide excision repair, homologous recombination, and other processes were also expressed differently in the treated and control rats. Through the autophagy-directed pathway, the protective effects of *C. ternatea* on the brain were shown. It concludes that the extract enhances memory by increasing the acetylcholine (ACH) in the brain. While the exact compound responsible for this needs

to be ascertained, the researchers hypothesize that *Clitoria ternatea*'s aqueous root extract could contain substances similar to brain-derived neurotrophic factor (BDNF) or nerve growth factor (NGF).

4.9. Antioxidant Activity

In the study by Phrueksanan et al. [29], the antioxidant and protective ability of the *Clitoria ternatea* petals (extracted in water and then spray-dried) were measured against in vitro 2,2′-azobis(2-methylpropanimidamide) dihydrochloride, (AAPH)-induced hemolysis and the oxidative damage of canine erythrocytes. The *C. ternatea* sample was checked against fresh whole blood, in which it was found that at 4 h after incubation, the extract (400 g/mL) significantly shielded erythrocytes against the AAPH-induced hemolysis. Additionally, it also inhibited the decline of glutathione content in the AAPH-induced oxidation of erythrocytes and decreased membrane lipid peroxidation and protein carbonyl group formation. The makers of this study attributed this to the anthocyanins, as they most likely quench peroxyl radicals before they damage the biomolecules of the erythrocyte membrane and trigger hemolysis, thereby preventing lipid peroxidation and GSH depletion. Since anthocyanins have the potential to scavenge free radicals and can attach to the lipid membrane of erythrocytes, they may be responsible for CTE's potent protection against AAPH-induced hemolysis in this research.

In another study [3], the DPPH radical scavenging activity of Clitoria ternatea tea was assessed against *C. ternatea* extract and a control sample with water, in which it signified that the *C. ternatea* beverage (tea) had a much higher ($p < 0.05$) antioxidant potential via DPPH radical scavenging activity, whereas the control sample of distilled water, as well as the *C. ternatea* extract, scored lower. This is representative of much larger literature in which the same or similar results were obtained, however, the study attributes this high antioxidant potential to lime juice, which was added to the beverage.

4.10. Anti-Bacterial Activity

Mahmad et al. [30] tested the ethanolic extracts of the blue variety flowers for *C. ternatea*, the results of which showed in vivo and in vitro antibacterial resistance. They used ethanolic red-colored extract and an aqueous blue extract of the blue flower variety and tested it against the bacteria *Bacillus subtilis*, *Staphylococcus aureus*, and *E. coli*, as well as fungi *F. sp.*, *A. niger*, and *T. sp* in agar and dextrose. The antibacterial activity against the same bacterium (*B. subtilis*) was demonstrated by both the in vivo and in vitro ethanolic extracts of *C. ternatea* L., with 11- and 10-mm inhibition zones, respectively, which they attributed to the activity of anthocyanins.

5. Application of *Clitoria ternatea* in the Indian Ayurvedic System

The Ayurvedic approach to disease prevention and health promotion takes into account the entire body, spirit, and mind when addressing health maintenance, development, and healing. It is a holistic strategy that is now becoming more popular throughout the Western world [31]. The root juice of the white-flowered *C. ternatea* is sprayed up the nose as a hemicrania therapy. An infusion or powder of the root is used to treat rheumatism and ear issues. It treats stomach, arthritis, fever, constipation, and eye issues. Additionally, it is used in cases of ascetics, abdominal visceral hypertrophy, sore throats, and skin problems. Ginger and finely ground seeds are employed as a laxative; however, the impact is accompanied by lower abdominal gritting. The seeds are also used to treat swollen joints, colic, dropsy, and abdominal visceral edema [4]. These therapeutic effects are displayed below in (Figure 1).

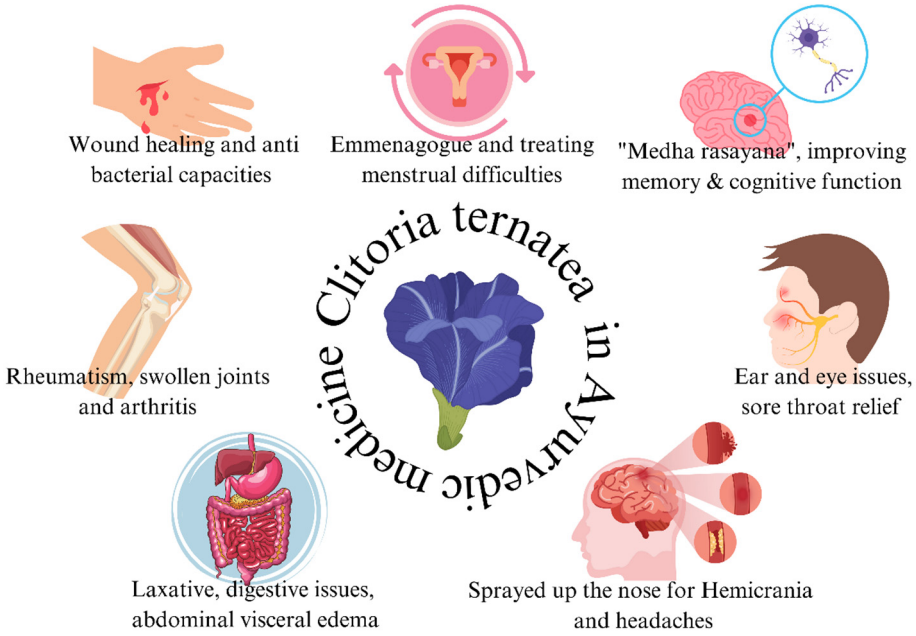


Figure 1. *Clitoria ternatea* in Ayurvedic medicine. Created with Canva.com (accessed on 20 April 2023).

The occlusive feature of the whole *C. ternatea* plant is ground to a paste and is mostly used on bleeding piles. Leaf juice is employed as a nasal drop for headaches. Because it stops the production of pus, *C. ternatea* decoction is useful for wound cleaning and stomatitis gargling. It is used to treat syncope, vertigo, and brain weakness since it also has a relaxing effect on the brain. Additionally, this type of medicine treats snakebite and scorpion stings by using the root, stem, and flower.

The Ayurvedic scripture refers to the juice from this flower as "medhya rasayana", which means "therapeutic procedure or preparation, that, if consumed regularly, will boost memory, intellect, and immunity", although the roots, leaves, and stems also have medicinal qualities. Due to its well-known effects on the brain and central nervous system, it is used to treat neurological problems, improve memory, and hone intellect due to these effects. It is widely used in Ayurvedic medicine as a memory-improving, anxiolytic, antidepressant, tranquilizing, and sedative drug [7,12].

6. Applications of *Clitoria ternatea* in South American Medicine

The indigenous people of South America had their own customary applications for the plant, similar to the Indian Ayurvedic system. Roots alone or with flowers are used in a decoction in Cuba as an emmenagogue to encourage menstruation and uterine contractions. A higher concentration of the same liquid is used as a vaginal douche. A potent treatment that is taken once daily to treat chlorosis, as well as liver and digestive problems, is produced when a little quantity of flowers and roots are blended with a bottle of excellent wine. According to folklore, the seeds have laxative, vermifugal, and mildly emetic properties [4].

7. Applications of *C. ternatea* in Experimental and Commercial Food Products

Clitoria ternatea extract is a natural blue colorant that is easy to use and has a longer shelf life than plant-based equivalents (because of Ternatin, the major anthocyanin present in this flower [32]). The instant color-changing ability of the extract of this flower has attracted attention from the hotel industry and food scientists alike [3]. Moreover, ready-to-eat foods are especially susceptible to oxidation. To counteract oxidative damage, synthetic antioxidants have been utilized. Natural antioxidants have increasingly replaced chemical preservatives in food products in recent years. Due to several pieces of research, which demonstrate the usefulness of blue pea extract in ready-to-eat food flavoring, due to its

antioxidant qualities, it can also be used for convenient ready-to-eat products [33]. These findings have been summarized in (Table 2).

Table 2. Applications of *C. ternatea* in experimental and commercial food products.

Type of Product	Testing	Outcome	References
Mocktails	Sensory evaluation of *C. ternatea* mocktails on a nine-point hedonic scale of three alternatives with apple, lemon, and orange.	*C. ternatea*, lemon-based mocktail drinks are preferred over other alternatives.	[34]
Fermented plant milk beverage	Assessment of chemical and physical properties of fermented drinks made from almond, soy, and almond-soy with *Clitoria ternatea* flower extracts (10%) and control sample (0%). Study method: CRD (complete randomization).	↑ antioxidant activity (74,665%) and ↑ protein content (342,695 mg/mL) for fermented almond milk beverages. ↓ viscosity of all *C. ternatea* fermented beverages. Hedonic sensory test: *C. ternatea* almond-soy > other beverages. For color: *C. ternatea* almond > other beverages.	[35]
Colorant powder	Identification of properties of spray-dried *C. ternatea* powder with maltodextrin and citric acid. Tested for yield, bulk density, moisture content, solubility, wetting ability, color intensity, total anthocyanin, and antioxidant activity. Extraction by 1:10 (distilled water: a combination of components).	↑ yield, bulk density, brightness, wetting ability, and solubility. ↓ water content, anthocyanin total, and antioxidant activity due to maltodextrin. Citric acid changes: Δ Hue of the powder (Blue→ Purple). ↑ anthocyanin content and ↓ antioxidant efficacy.	[36]
Ice cream (With banana flour)	*C. ternatea* powder as a natural colorant in prebiotic banana flour ice cream with single strain Bifidobacterium animalis (Bb-12) and banana flour (0%, 10%, 20%, 30% *w*/*w*) with a constant level of (0.67% *w*/*v*) *C. ternatea* powder.	*C. ternatea* total anthocyanin content: 1168.92 mg L^{-1}. Probiotic viability ↑ during storage (109 CFU mL^{-1}). Sensory assessment: 20% banana flour > other samples.	[37]
Chinese steamed bread	To test the effect of *C. ternatea* (aqueous extract of dried flowers) (0–30%) on the phytochemical, textural, and sensory properties of the steamed bread.	↑ total anthocyanins, antioxidant activities, and free polyphenols. ↓ springiness, cohesiveness, and elasticity of the 30% bread. Ideal concentration: 20–30% *C. ternatea* ↓ anthocyanin content and blueness of bread due to steaming.	[38]
Jelly	Creation and assessment of commercially viable jelly with *C. ternatea* (aqueous extract). Different jelly compositions using fruit pulp and *C. ternatea* extract were created. Its color, pH, moisture, titratable acidity, fiber, ash, and calorie value were assessed. A nine-point hedonic scale test was used to assess the sensory evaluation for taste, texture, color, smell, appearance, and general acceptability.	Δ in the sensory evaluation for taste, texture, color, smell, appearance, and general acceptristics for all jellies. Moisture content range: 13.1% to 20%. ↑ ash content for *C. ternatea* jelly. ↑ fiber content of banana pulp-infused jelly. Titratable acidity range: 0.02% to 1.023%. Energy value: 357.03 to 428.66 J/100g. Sensory analysis: *C. ternatea* watermelon jelly > other samples.	[39]
Milk and white chocolate	Evaluation of *C. ternatea* powder (0%, 5%, 10%, and 15%) in milk and white chocolate for color, hardness, and sensory aspects (color, scent, taste, texture, and overall).	Δ evaluation of *C. Ternatea* powder (0%, 5% *Clitoria ternatea* powder to milk compound chocolate and white compound chocolate ($p = 0.05$). Sensory analysis results: 0% *C. ternatea* > other samples.	[40]
Water kefir	To optimize fermentation time (24–48 h) and concentration grain (5–15%) for *C. ternatea* water kefir with a good antioxidant activity using response surface methodology.	↑ antioxidant activity (58 ppm) and ↑ TPC Ideal conditions: 36 h 2 min fermentation time and 15% grain concentration.	[41]

Table 2. *Cont.*

Type of Product	Testing	Outcome	References
Yogurt	To check the antioxidant activity and color values of *C. ternatea* yogurt made from liquid skim milk, ultra-high temperature (UHT) milk, pasteurized milk, UHT milk with skim powder, and pasteurized milk with skim powder. Aqueous extract at 3:1 (g L^{-1}) ratio under 45 min at 60 °C. Yogurt incubated for 24 h at 37 °C.	↑ antioxidant activity after the addition of *C. ternatea*. ↑ antioxidant activity from skim milk. Maximum antioxidant activity: skim milk *Clitoria ternatea* yogurt (437.04 ppm), with L*, a*, and b* values: 37.35, 2.02, and −1.32.	[42]
Juice	Analyzed for total anthocyanin content remaining after processing (5% BPF extract (*v*/*v*), sterilized at 125 °C for 3 min with an extended storage time of 4+ months).	Slow degradation of anthocyanin content during storage.	[43]
Beverage (tea)	To check the ideal ratio for a *C. ternatea* beverage with natural sweetener (Stevia extract) and a flavor (lime). Response surface methodology and Box-Behnken design used for extraction formulations. Antioxidant activity was assessed by ORAC, DPPH, and ABTS. Antiamylase and antiglucosidase activities of glycaemic regulatory properties (GCP) were also assessed. Checked over the course of 28 days at various intervals.	Ideal extraction conditions: 3 g of powdered *Clitoria ternatea*/L of water for 37 min at 59.6 °C. ↑ antioxidant activity. No glycaemic regulatory properties. A 28-day shelf life without preservatives.	[3]
Gin	*C. ternatea* flower extracts are utilized to make a blue alcoholic gin that changes color in response to pH, e.g., with tonic water or lime.	This is a commercial product.	[1]
Sponge cakes	Assessment of sponge cake with *C. ternatea* extracts (0, 5, 10, 15, and 20%, *w*/*w*) for color, volume, water activity, total phenolic content, antioxidant properties, texture, and consumer acceptability.	↑ polyphenol content and antioxidant activity, ↓ lipid peroxidation. ↑ *C. ternatea* extract led to ↑ hardness, adhesiveness, gumminess, and chewiness. ↓ cohesiveness, springiness, and resilience. Color analysis: ↓ lightness, redness, and yellowness.	[44]
Cupcake	Differences in lipid, moisture, pH, protein, and ash. Sensory tests for control sample vs *C. ternatea* cupcake (50 g diluted flower, water, or ethanolic mixture extract at a 1:80 ratio).	↑ moisture (22.12 ± 1.87), protein (3.69 ± 0.51) ↓ pH (7.08 ± 0.54), ash (1.01 ± 0.21), and lipid (12.10 ± 2.77) Sensory: *C. ternatea* sample > control sample.	[45]
Cooked pork patties with incorporated *Clitoria ternatea*	Checking the effectiveness of *C. ternatea* extract at preventing protein and lipid oxidation in cooked pork patties stored in the refrigerator. The cooked pork meats were kept in a refrigerator (4 °C) for 12 days after being mixed with *C. ternatea* extract (0.02–0.16% *w*/*w*).	↑ radical scavenging activity. ↑ protein oxidation for *C. ternatea* patties, ↓carbonyl concentration, and ↑ protein thiol levels. *C. ternatea* extract (0.08–0.16%) has the same ability as synthetic antioxidants to prevent oxidative rancidity (0.02 percent BHT).	[33]
Fried meat-stuffed rice ball (viên thịt)	Analyzed for total anthocyanin content remaining after processing (10% extract (*v*/*w*)—frying time 4 min).	↑ anthocyanin content and stability during frying.	[43]

Table 2. *Cont.*

Type of Product	Testing	Outcome	References
Bread and bread flour	Impact of *C. ternatea* extract on inhibiting pancreatic-amylase, in vitro starch hydrolysis, and forecasting the glycaemic index of potato, cassava, rice, corn, wheat, and glutinous rice flour. Sponge cakes were infused with five different levels of CTE (0, 5, 10, 15, and 20%, *w*/*w*) and were assessed for color, volume, water activity, total phenolic content, antioxidant capabilities, and consumer approval.	↓ pancreatic-amylase activity for 1% and 2% (*w*/*v*) *C. ternatea* extract in all flours. ↓ release of glucose, the hydrolysis index (HI), and the projected glycemic index (PGI) for 0.5%, 1%, and 2% (*w*/*v*) *C. ternatea* in wheat. ↓ quickly digestible starch (RDS) and slowly digestible starch (SDS), ↑ undigested starch in glutinous rice flour with 1% and 2% (*w*/*v*) *C. ternatea* extract. Statistical results: positive associations between *C. ternatea* extract and undigested starch in wheat and cassava. ↓ speed for starch digestion with the addition of 5%, 10%, and 20% (*w*/*w*) *C. ternatea* extract. ↓ PGI for 5% *C. ternatea* bread.	[46]
Muffins	Application of *C. ternatea* anthocyanin microcapsule on muffins as a bio-preservative (5 g spray-dried flower acetic water extract: muffin dough).	↑ inhibitory activity for gram +ve and gram -ve bacteria. ↑ shelf life.	[47]
Rice ball sweet soup (chè ỉ)	Analyzed for total anthocyanin content remaining after processing. (15% extract, boiling time of 6 min).	Stable anthocyanin content for up to 9 min of boiling.	[43]
Cooked rice	*C. ternatea* flower (CTE) extracts of 1.25 and 2.5% (*w*/*v*) were added to cooked rice using conventional cooking techniques to study the impact on starch digestibility.	↓ readily digestible starch and ↑ undigested starch. ↑ stickiness and unchanged hardness. Sensory evaluation results: "mostly acceptable". Overall findings: *C. ternatea* is an effective component for reducing starch digestibility when combined with cooked rice.	[48]
Ice cream	Sensory evaluation via flavor, appearance, texture, aroma, and color. General acceptability for consumers for *C. ternatea* ice cream.	Overall acceptability by consumers for ice cream.	[49]

8. Scope of *Clitoria ternatea* as a Future Food

As large-scale plant material collection is unlikely to be commercially viable, there is presently no manufacture of *Clitoria ternatea* for anthocyanins. According to one research, new advances in developing plant cell suspension cultures with anthocyanin regulatory pathway genes offer a more practical substitute. However, another study contends that *C. ternatea* does not face the problem of a lack of source material, which is one of the most significant limitations in the development and commercialization of natural products. Nevertheless, despite counterarguments, it is projected that adopting *C. ternatea* as a functional component will stimulate the in-depth study of the plant and result in fresh discoveries that could result in second- and third-generation products. Since just a handful of the cyclotides in *C. ternatea* have been studied for potential medical uses, greater study, such as molecular grafting frameworks to introduce new desirable pharmacological properties, can be encouraged, as many have performed for cyclotides from other plants [1,50].

9. Conclusions

The *Clitoria ternatea* flower is part of a plant that contains several functional bioactive compounds which are beneficial to the human body, such as anthocyanins, flavonoids, fatty acids, tocols, and phytosterols. Along with its functional properties, it also possesses anti-

helminthic, anti-fungal, anti-insecticidal, and anti-bacterial properties, which were used to develop an insecticide. It is a tropical plant and is generally found in Asia, South America, and certain parts of Australia. In certain South American cultures, and in Southeast Asia, it is also a part of traditional medicine and has been used to treat illnesses and enhance bodily functions such as menstruation and cognitive functions. The early natives of these places regarded this flower for its effect on the nervous system and brain, as well as others such as curing of fevers, healing of bruises, and even anesthetic properties. It should also be noted that several properties of this plant and flower could be studied at the same time, for example, the studies of the anti-inflammatory, anti-arthritis, and analgesic effects. This denotes that the plant exhibits multiple pro-health properties and can be used for multiple health ailments at the same time.

In modern gastronomy, this flower has been gaining massive popularity due to its color-changing ability in the presence of an acidic or alkaline pH. Thus, it has become the focus of some studies including blue-colored rice, ice cream, bread, cakes, and others. It was also checked for being an antioxidant in products such as pork patties and meatballs.

Lastly, this flower has the potential to become a future food. This is because the world's food reserves are depleting continually and, eventually, the direction of food science will turn to alternative foods and sources of bioactive compounds such as anthocyanins and flavonols, which are widely present in this flower.

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