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An Overview of *Clitoria ternatea* L.'s Phytochemical Profile and Antioxidant Potential for Use as a Natural Food Colorant

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Abstract: ***Food colourants play a crucial role in the food industry by enhancing sensory appeal and consumer acceptability. With increasing demand for natural, eco-friendly, and functional food additives, plant-derived pigments have emerged as promising alternatives to synthetic dyes. Clitoria ternatea L., commonly known as the butterfly pea plant, is a rich source of bioactive compounds, particularly polyacylated anthocyanins known as ternatins. These compounds impart a vivid, stable blue coloration, especially in acidic media, addressing the industrial challenge of obtaining stable natural blue colourants. This review summarizes the botanical taxonomy, phytochemical profile, structural stability, antioxidant properties, traditional and modern culinary applications, and safety aspects of C. ternatea as a multifunctional, natural food colourant.***

Keywords: Food colourant, eco- friendly, *Clitoria ternatea*, anthocyanins, ternatins

1. Introduction

Clitoria ternatea L., known as butterfly pea flower, belongs to the family Fabaceae. is a perennial herbaceous climbing vine that thrives in moist, neutral soils. The Latin genus name Clitoria references the visual similarity of the solitary flower to human female genitalia. The flowers are approximately 4 cm long by 3 cm wide, featuring a deep blue hue with light yellow markings, though white-flowered varieties also exist. The plant produces flat pods (5–7 cm long) containing six to ten seeds, which are edible when tender. In traditional culture, such as in India, the flower holds sacred status and is routinely used in daily puja rituals. It is also edible, with medicinal and ornamental value. Historically, it is utilized in traditional systems of medicine such as Ayurveda; the plant's vibrant deep - blue colour is of interest in food science and nutraceuticals.

Systematic position:

Kingdom	:	Plantae
Class	:	Dicotyledons
Subclass	:	Polypetalae
Series	:	Calyciflorae
Order	:	Fabales
Family	:	Fabaceae
Genus	:	*Clitoria*
Species	:	*Clitoria ternatea* L.

Phytochemical and Nutritional Composition

Phenolic compounds and other bioactives, such as alkaloids, tannins, glycosides, steroids, saponins, flavonoids, and phenols, are abundant in its flowers, particularly the petals [1]. Most of the unique secondary metabolites and their analogues identified in this plant are anthocyanins, including ternatins, preternatins, cyanidin, and delphinidin, along with phenolic acids, terpenoids, and phytosterols derived from the flowers [2]. Flavonol glycosides, myricetin, quercetin, phenolic acids, kaempferol, and anthocyanins are examples of primary secondary metabolites [3,4]. Anthocyanins are useful as natural food coloring because of their vivid coloration and safety when consumed. However, their poor stability in aqueous environments limits their use, especially when there are changes in temperature, light, pH, oxygen, metal ions, and enzyme activity [5].

Food colourants are crucial to the food business because they change or add colors to food to make it more appealing to consumers and more palatable to their senses. They are classified into synthetic and natural categories based on their origin. Synthetic dyes are increasingly being replaced by natural pigments such as anthocyanins, carotenoids, and chlorophylls extracted from plants and microorganisms. Among plant sources, *Clitoria ternatea* L. (family Fabaceae), commonly named Asian pigeonwings, blue pea, butterfly pea, blue bell vine, blue ternate, or Darwin pea, stands out due to its distinct, vibrant blue flowers. *Clitoria ternatea* blooms are rich in phenolic chemicals and diverse bioactive compounds. Neda et al. reported the nutritional composition of C. ternatea flowers, and the flowers display a high moisture content (92.4%), with the remaining dry matter containing macronutrients and essential minerals.

Table 1: Nutritional and Mineral Composition of *C. ternatea* Flowers

Category	Components	Value
Macronutrients	Moisture	92.4%
	Fat	2.5%
	Carbohydrates	2.2%
	Crude Fibre	2.1%
	Protein	0.32%
Minerals	Magnesium	2.23mg/g
	Potassium	1.25mg/g
	Zinc	0.59mg/g
	Sodium	0.14mg/g
	Iron	0.14mg/g

Phytochemical Spectrum

Structural transformations of anthocyanins in response to pH shifts are closely linked to changes in extract coloration. The anthocyanins demonstrate an intense and stable blue colour in an acidic medium, which facilitates their application in acidic food systems as a blue food colouring agent. Acidic extracts have greater storage stability than alkaline conditions, even though browning may not happen between pH4–6 and no brown precipitate forms between pH 0.5–13 at different temperatures. The search for plant-derived substitutes for synthetic colorants, especially those that offer both functional and visual advantages, has been spurred by the growing demand for natural food additives. Among these, anthocyanins are a class of water-soluble flavonoid pigments that have attracted a lot of interest because of their dual function as bioactive substances with strong antioxidant qualities and natural colorants. The development of stable blue coloration in food systems continues to be a challenge because blue pigments are uncommon in nature and tend to break down under different environmental conditions like pH, light, and temperature [6].

Hydrophilic Secondary Metabolites: The primary bioactive components within the petals include flavonoids, flavonol glycosides (myricetin, quercetin, kaempferol, and rutin), phenolic acids, alkaloids, tannins, steroids, saponins, and anthocyanins. Malonylated flavonol glycosides are also present. Lipophilic Constituents: Lipophilic extracts yield tocols, phytosterols (campesterol, stigmasterol, beta-sitosterol, and sitostanol), and fatty acids (petroselinic, linoleic, arachidic, behenic, and phytanic acids).

Anthocyanins, Structural Stability, and Coloration Dynamics

Developing stable blue natural colourants poses a significant technical challenge in food processing, as blue pigments are rare in nature and often degrade rapidly under varying environmental conditions such as light, temperature, pH, oxygen, metal ion presence, and enzymatic activity. Standard anthocyanins from fruits and vegetables typically yield red-to-purple shades and decompose in non-acidic environments. Since there are limited blue food colourants available, blue pea flower anthocyanins will be a good alternative to be used as a natural blue food colouring agent [7].

C. ternatea flowers derive their deep blue pigment from ternatins, a unique subclass of polyacylated anthocyanins. The polyacylated structure confers superior structural stability compared to non-acylated anthocyanins, rendering them less susceptible to thermal and photo-induced degradation. The structural transformations of *C. ternatea* anthocyanins are directly linked to pH changes: Acidic extracts demonstrate higher storage stability than alkaline extracts. No brown precipitate forms across a broad pH spectrum (pH 0.5–13) at various temperatures, and browning is suppressed between pH 4–6. These properties allow ternatins to maintain an intense blue hue in acidic food systems, such as beverages and confections, where conventional anthocyanins would shift to red or degrade.

Bioactivity and Health Benefits

Beyond their role as colourants, *C. ternatea* extracts serve as functional ingredients with health-promoting properties. Other published research reported the medicinal effects of C. ternatea, such as antipyretic, analgesic, and anti-inflammatory effects, which are good for one's health and well-being because they help to reduce health disorders. The flower is traditionally used as a diuretic, anthelmintic, bronchitis, purgative, urinogenital disorder, demulcent, and anticancer [8]. The antioxidant activity of butterfly pea anthocyanins stems from their ability to donate hydrogen atoms or electrons to free radicals, neutralizing them and preventing oxidative damage. Extracts are evaluated using standard assays such as the Folin-Ciocalteu assay for Total Phenolic Content (TPC) and the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging assay. *C. ternatea* anthocyanins exhibit strong antioxidant action both in vitro and in vivo. Because of their antioxidant properties, blue pea flower anthocyanins are thot to be able to treat diabetes, cancer, and neurological and cardiovascular.

In traditional Ethnomedicine, *C. ternatea* has been utilized for millennia as a nootropic, memory booster, stress reliever, anxiolytic, antidepressant, anticonvulsant, sedative, and tranquilizer. Additional reported traditional uses include antipyretic, analgesic, anti-inflammatory, diuretic, anthelmintic, purgative, demulcent, and treatment for respiratory and urogenital disorders. In traditional Ayurvedic medicine, it has been used for millennia as a nootropic, stress reliever, anxiolytic, antidepressant, anticonvulsant, sedative, tranquillizer, and memory booster.

Food Applications and Thermal Stability

C. ternatea has a long history of culinary use in Asian countries, such as China and Malaysia, where it is used to brew blue-colored tea and prepare traditional blue rice (Nasi Kerabu). Modern food formulation has expanded its application into diverse matrix systems. Several studies have investigated the use of blue pea flower anthocyanins as a food colourant in bakery products, yoghurt, and functional beverages. Further research should be carried out on the application of blue pea flower anthocyanins in other food systems. Studies have shown antioxidant and antimicrobial activities of blue pea flower anthocyanins in different applications. Further research could be carried out to investigate the bioavailability and other functional properties of blue pea flower anthocyanins. Because blue food colourants are limited, blue pea flower anthocyanins could be a good alternative as a natural blue food colouring agent.

Table 2: Culinary Applications of *C. ternatea* Natural Extract

Food Matrix	Application	Reference
Gummy candy	Incorporated as a natural blue dye agent	[9]
Noodles	Used as an aqueous blue extract dye	[10]
Cup-cakes/Rolls	Imparts visual appeal; thermal processing at 170°C for 20 min caused a 41.8% loss of anthocyanins.	[11,12]
Traditional Rice	Blue rice formulation utilizing flower infusions.	[13]
Chia Pudding & Desserts	Extract applied to eliminate artificial dye usage.	[14]
Functional Beverages / Tea	Evaluated for market acceptability and health benefits	[15,16]

2. Conclusion

The present study demonstrates that natural colorants from *Clitorea ternatea* can be effectively extracted and utilized in food products, offering several health benefits. These biodegradable dyes have minimal environmental impact and are derived from renewable sources. The research highlights the promising use of these flowers in creating appealing colors in various foods, such as cupcakes, candies, and beverages, making them attractive to all age groups. Promoting natural dyeing in the food sector is vital for sustainability and health. Blue pea flower anthocyanins, derived from *Clitoria ternatea*, serve as a promising natural blue food coloring agent due to their intense and stable color in acidic environments. They exhibit higher stability than non-acylated anthocyanins and possess antioxidant properties, making them suitable for functional foods underscores its industrial potential. Research indicates their application in products like bakery items, yogurt, and beverages. However, further studies are needed to explore their use in other food systems, as well as their bioavailability and functional properties.

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Conflict of Interest
Disclosure of conflict of interest
No conflict of interest to be disclosed.

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