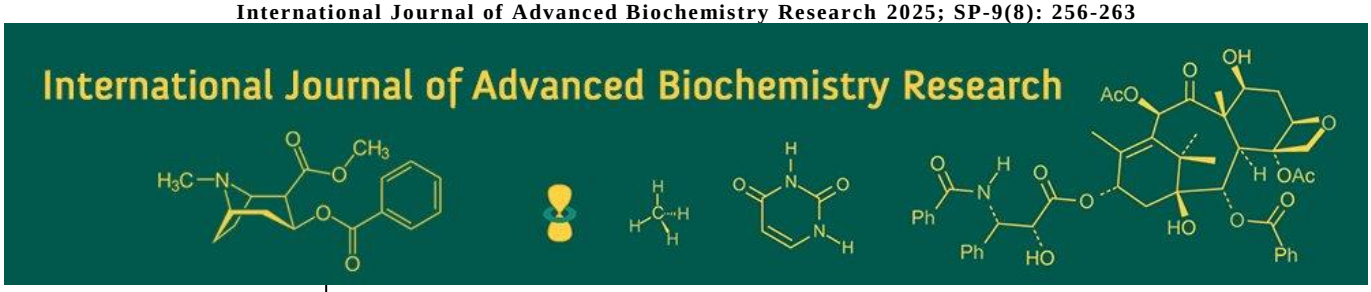

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M Yuvaraju
Department of Processing and food Engineering, Dr. NTR College of Agricultural Engineering, Bapatla, Angrau, Andhra Pradesh, India

P Sreedevi
Principal Scientist (Agril. Engg.), Post-Harvest Engineering and Technology, Regional Agricultural Research Station, Anakapalle, Angrau, Andhra Pradesh, India

BVS Prasad
Principal Scientist (Agril. Engg.), Department of Processing and Food Engineering, Angrau, Lam Guntur, Andhra Pradesh, India

M Sandhya
Associate Professor, Department of Bio Chemistry, Agricultural college, Bapatla, Angrau, Andhra Pradesh, India

Corresponding Author:
M Yuvaraju
Department of Processing and food Engineering, Dr. NTR College of Agricultural Engineering, Bapatla, Angrau, Andhra Pradesh, India

A comprehensive review of *Clitoria ternatea* L. flower-extraction and application in food industry

M Yuvaraju, P Sreedevi, BVS Prasad and M Sandhya

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Abstract
Clitoria ternatea L., (Butterfly pea) is the ornamental plant grown worldwide with many medicinal and therapeutic properties. The butterfly pea plant is rich in bio active compounds and known for applications in various aspects of medicine, cosmetics, agriculture and food industry. The flower of this plant is a rich source of anthocyanin's that accounts for deep natural blue color. This paper presents a brief review on the traditional and novel technologies for extraction of bioactive compounds from the butterfly pea flower and its application in food industry. Traditional method of extraction of food color from these flowers results in degradation of anthocyanin and phenolic compounds at high extraction temperature. Non-thermal extraction methods like Ultrasound-Assisted Extraction (UAE), Microwave-Assisted Extraction (MAE) proved to be beneficial in preserving the heat-sensitive compounds such as anthocyanins and flavonoids. UAE creates cavitation for cell disruption whereas MAE uses dielectric heating for faster cell rupture for extraction of bioactive compounds. The anthocyanin extracted from butterfly pea flower has a potential as natural food colorant and has wide application in bakery foods, yoghurts, functional desserts. The unique property of change in color of anthocyanin's extracted from this flower from blue to purple with change in pH was used in monitoring food spoilage. Hence, the anthocyanin extract from butter fly pea flower can function as promising natural colorant alternative to synthetic blue color as well used in intelligent packaging in food industry.

Keywords: Butterfly pea flower, anthocyanin, Non-thermal extraction, natural food color and intelligent packaging

Introduction
Color plays a vital role in food industry as it enhances the acceptability and attractiveness of the product. Synthetic food colors are generally added to enhance the visual appearance of food, particularly to capture the attention of children. Consumption of artificial food colors is interrelated with various health concerns, including depression, memory loss, and increased aggressiveness. Regular intake of food products containing these synthetic color additives can also result in significant health issues, such as the oxidation of fatty acids, skin irritation, food intolerance, irritability and sleep complaints in children (Feketea and Tsabouri, 2017) [11]. With an increasing consumers' preference towards natural products, these synthetic colors are replaced by natural colors. Natural food colors originate from several sources such as vegetables, fruits, spices, and algae covering a wide range of dyes or pigments (Mohamad *et al.*, 2019) [29]. The natural food colors that are derived from natural pigments include anthocyanin, betanin, carminic, chlorophyll, carotenoids, curcumin, carbon black, etc. (Malabadi *et al.*, 2022) [24]. In addition to food coloring, these natural colors have a variety of health benefits such as antioxidant, anti-cancer, and anti-inflammatory properties (Singh *et al.*, 2023) [42]. Natural food colorings maintain the products with good consistency and taste, more environmentally friendly, non-toxic, and biodegradable. Though many sources are available from plants worldwide for the extraction of natural colors, only a small amount has been extracted so far. Hence, more scientific studies are needed to exploit the underutilized plant sources for the extraction of natural food colors, as they are in high demand for use in food and therapeutic formulations of natural drugs.
Clitoria ternatea L., is one of the emerging plants with many medicinal and therapeutic properties and rich source of antocyanins with natural blue color. The butterfly pea (*Clitoria ternatea L.*) is an ornamental plant belonging to the Fabaceae (Leguminosae)

family (Tantituvanont *et al.*, 2008) [46]. Originally native to Central and South America, it has now spread across tropical regions, including Africa, Asia, Australia, and the Caribbean. It is commonly known as butterfly pea, conch flower, or shankapushpi, with regional names like Aparajit (Hindi), Aparajita (Bengali), and Kakkattan (Tamil) in Indian traditional medicine (Mukherjee *et al*, 2008) [30]. This perennial herbaceous vine thrives in moist, neutral soils and is characterized by its elliptic, rounded leaves and striking deep blue flowers with light yellow markings, though some varieties produce white or pink blooms. It holds cultural and medicinal significance, particularly in Southeast Asia and India, where it has been used from time immemorial for its therapeutic benefits and diverse applications. Its vibrant flowers also make it a popular ornamental plant (Michael and Kalamani, 2003) [28]. In regions like Kerala (India) and the Philippines, young shoots, leaves, flowers, and tender pods are consumed as vegetables, while in Malaysia, the leaves add a green tint to dishes, and the flowers provide a striking blue hue to rice cakes. The plant offers green fodder throughout the year, making it particularly valuable during dry periods. It is grown across several Indian states, including Punjab, Rajasthan, Uttar Pradesh, Gujarat, Maharashtra, Madhya Pradesh, Andhra Pradesh, Tamil Nadu, and Karnataka, either independently or with perennial grasses. It is widely used as a drought-resistant pasture in arid and semi-arid regions (Oguis *et al.*, 2019) [33]. Every part of the plant, from its roots, stem, flowers fruits and seeds serve a functional purpose, making it a valuable botanical resource (Fig 1).

Nutritional Composition

Butterfly pea (*Clitoria ternatea* L.) is a nutrient-rich plant recognized for its numerous health benefits. The plant is rich in minerals such as Calcium (1.5-25.9 g/kg), Phosphorus (0.3-3.9 g/kg), Potassium (7.7-23.0 g/kg), Sodium (0.3-1.1 g/kg), Magnesium (3.2-6 mg/kg) etc. (Weerasinghe *et al.*, 2022) [52]. Its seeds contain good amounts of essential fatty acids, including palmitic acid (19%), stearic acid (10%), oleic acid (51-52%), linoleic acid (17%), and linolenic acid (4%) (Grindley *et al.*, 1954 [16]; Joshi *et al.*, 1981) [18]. The seed's caloric value is estimated to be approximately 500 calories per 100 grams (Joshi *et al.*, 1981) [18]. The flower of this plant is rich source of anthocyanin's called Ternatins namely A1, A2, B1, B2, D1 and D2. It was reported that fourteen flavonoids were present in the petals of the flower (Mukherjee *et al.*, 2008) [30]. The flower and leaves of the plant has high antioxidant properties and plays vital role in free radical scavenging activity. This plant provides a moderate amount of protein and dietary fiber, both of which support digestion and boost metabolism (Barro *et al.*, 1983) [4]. The high concentration of essential fatty acids particularly oleic, linoleic, and palmitic acids, plays a crucial role in heart health and cellular function (Weerasinghe *et al.*, 2022) [52]. Additionally, the plant is a source of essential vitamins and minerals such as vitamin C, calcium, iron, and phosphorus, which contribute to bones strength, immune function, and red blood cell production (EFSA, 2022) [10]. In total, each and every part of the plant is rich in nutrients and has plenty of health benefits.

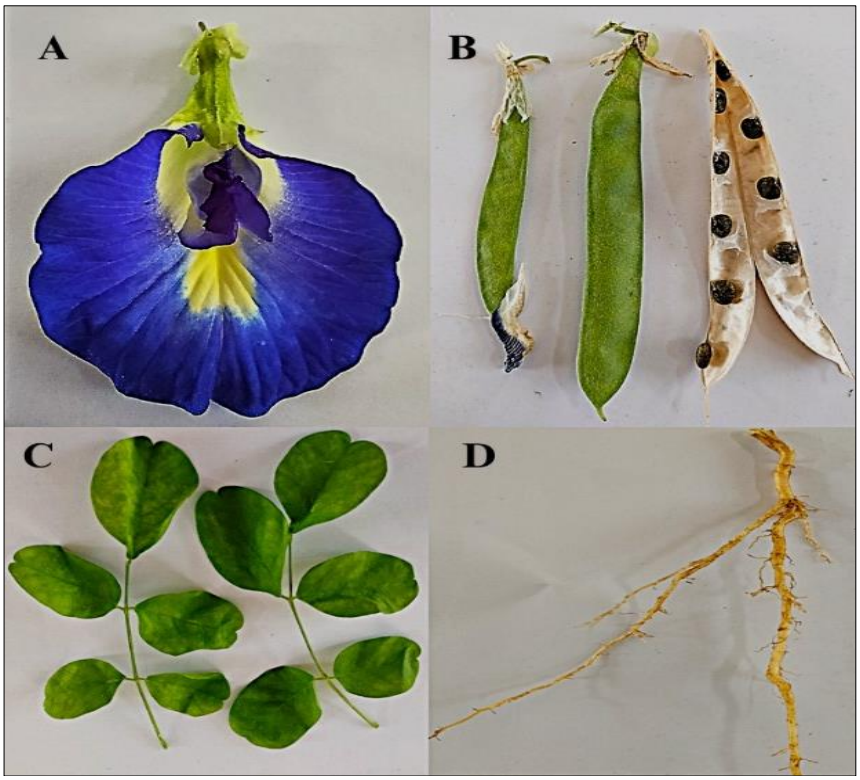

Fig 1: Parts of the butterfly pea plant (a) flower (b) seeds (c) Leaves (d) root

Extraction of butterfly pea flower extract

The butterfly pea flower is rich source of anthocyanins with high stability thus providing great source as natural food coloring agent. The Polyacylated derivatives of delphinidin 3,3',5'- triglocoside, named "Ternatins" are the major anthocyanin's responsible for blue color in butterfly pea flower (Vidana Gamage *et al.*, 2021a) [50]. The unique feature of this anthocyanin is its shift to different colors with change in pH. Escher *et al.*, (2020) [8] reported that the anthocyanin's extract of this flower exhibit red color with pH less than 3.2 and the color changes from violet to blue with change in pH from 3.2 to 5.2, light blue color when pH

change from 5.2 to 8.2, and light blue to dark green with pH change from 8.2 to 10.2. This peculiar feature of change in color with pH can be well utilized in food industry as per consumer's acceptance. Especially, the blue color anthocyanins of this flower can be used as blue coloring agent in acidic and neutral food stuffs.

Conventional Methods of extraction

The extract from the butterfly pea flower was prepared either from fresh flowers or from dried petals of the flower. The extraction can be done in two methods, conventional/traditional and non-conventional methods. The conventional methods used for extraction of anthocyanins from butterfly pea flower are maceration, Soxhlet extraction & hot/cold water extraction. Maceration method involves soaking the flower in water at room temperature over an extended period, allowing the water to penetrate into tissues to dissolve the desired phytochemicals. Zuki and Hadzir (2024) [55] reported that maceration can effectively extract significant amounts of phytochemicals from *Clitoria ternatea* L. flowers and the yield of phytochemicals increased by 16-247% compared to other methods. In hydro-alcoholic method, ethanol, methanol or distilled water are used as solvents. Selection of suitable extraction method helps for maximum yield with high concentration of the bioactive compounds. Extraction of bioactive compounds from this flower depends on various factors such as solvent used for extraction, pH of the solvent, substrate: solvent ratio, extraction temperature, extraction and soaking time. Different solvents such as ethanol, methanol, and with combination with water, acetone, distilled water were used for extraction of anthocyanins. During extraction of anthocyanins for usage as food colorant, the use of toxic organic solvent should be avoided (khoo *et al.*, 2017 [20]; Chemat *et al.*, 2019) [5]. Ludin *et al.*, (2018) [22] found ethanol to be the most efficient solvent for anthocyanin extraction, while ethyl ether was the least, highlighting the role of solvent polarity in extracting polar compounds. It was reported that distilled water is the best solvent for extraction of anthocyanin's as water is non-toxic, non-flammable and low-priced green solvent (Chemat *et al.*, 2019) [5]. Ahmad *et al.*, (2020) [2] reported that substrate: solvent ratio of 1: 20(g/ml) is the best for high extraction of anthocyanins from butterfly pea flower, temperature around 50-60 ºC and extraction time of 20-60 minutes would yield high extraction of anthocyanin. Prolonged heating and high temperature results in degradation of anthocyanins. The anthocyanin extract obtained using water with pH 1 was higher than that of pH 2 (Saptarani and Suryasaputra, 2018).

Non -Conventional Extraction Methods

The conventional method of extraction of bioactive compounds consumes more time, more solvent and high temperatures resulting in degradation of heat sensitive compounds and thus the non-conventional techniques were explored. Ultrasound-assisted extraction (UAE) has been extensively studied for its effectiveness in extracting bioactive compounds from *Clitoria ternatea* L. (butterfly pea) flowers. This method utilizes ultrasonic waves to enhance solvent penetration and disrupt plant cell walls, leading to improved extraction efficiency. Wijaya *et al.*, (2021) showed UAE improved anthocyanin extraction from *Clitoria ternatea* L. for pH indicators, enhancing yield and stability for use in biodegradable, color-changing food packaging films. Glycerol-based extraction is an eco-friendly method for isolating bioactive compounds and it enhances phenolic and flavonoid yields from *Clitoria ternatea* L., with optimized UAE using a 60:40 glycerol-water mix (Shu *et al.*, 2022) [39]. Glycerol improves anthocyanin stability and extraction efficiency (Gew *et al.*, 2024 [14]; Vidana Gamage *et al.*, 2021b) [51].

Microwave-assisted extraction (MAE) has been explored as an efficient method for extracting anthocyanins and other bioactive compounds from *Clitoria ternatea* L. flowers. This technique utilizes microwave energy to rapidly heat the solvent and plant material, enhancing extraction efficiency and reducing processing time. Marsin *et al.*, (2020) [26] used MAE (770 W, 1 min) for anthocyanin encapsulation, enhancing stability for food and cosmetics. Various extraction methods have been explored for *Clitoria ternatea* L., each with unique advantages. Maceration is simple but time-consuming, while ethanol and glycerol-based extractions enhance phenolic and anthocyanin yields. Ultrasound-assisted (UAE) and microwave-assisted extraction (MAE) improve efficiency, with UAE optimizing solvent use and MAE accelerating processing time. These techniques provide eco-friendly and effective ways to extract bioactive compounds for food, cosmetics, and pharmaceutical applications. The reviews on extraction of bioactive compound from butterfly pea with different solvents are given in Table 1.

Table 1: Studies on extraction of bioactive compounds from butterfly pea flower

S. No	Extraction method	Extraction solvent and optimum conditions	Results	References
1	Ultrasound assisted extraction (UAE)	Distilled water, 70% ethanol- water and phosphate buffer (pH 7) Time - 35 min Solid- solvent ratio - 1:30 gmL^{-1} Ultrasonic power -225 W	Highest TAC of 49.26±0.2 mg CEg^{-1} was observed using phosphate buffer.	Siddiqui *et al.*, (2025) [40]
2	Ultrasound-Assisted Extraction	Natural eutectic solvent (choline chloride/glycerol, CHCl: Gly). Time - 50 min Temperature - 80 ºc Petal - solvent ratio- 7%	The CHCl: Gly solvent resulted in higher anthocyanin levels of 374.65 mg DGE/L compared to water 211.63 mg DGE L^{-1} Storing the CHCl: Gly extract as solvent at 5 ºc reduced anthocyanins to 16%.	Maia *et al.*, (2025) [23]
3	Ultrasound-Assisted Extraction (UAE)	High-purity water with conductivity of approximately ±15 µS Time - <30 min Temperature - 70 ºc S/L ratio- 1:30	Highest TAC of 16.5234 gL^{-1} was reported using high purity water compared to conventional method	Mustika *et al.*, (2024) [31]
4	Comparison between water extract and ethanol extract	Distilled water, ethanol 96% Time - 15 min	Highest flavonoid content of 7,804 $mgQEg^{-1}$ and antioxidant activity IC50 of 86.67 ppm was reported in water extract	Nurhayati *et al.*, (2024) [32]

5	Ultrasonic assisted extraction (UAE)	Acidified water (pH 4) Time - 30 min Temperature - 30 °c S-S ratio-1:4 (w/v)	Highest TAC of 261.28 mgL^{-1} was observed for raw butterfly pea extract compared to liquid butterfly pea extract of 32.272 mgL^{-1}	Hamdan *et al.*, (2024) [17]
6	Comparison between Hot water extraction, Ultrasound-assisted extraction, Microwave-assisted extraction and Pectinase-assisted extraction	Water Time - 30 min Temperature - 50°C S/L ratio - 1: 15 Power - 230 W (UAE) Power - 800 W (MAE)	Highest extraction yield of 56.9% by hot water extraction Highest TAC of 9.61 mg $CGEg^{-1}$, TPC of 110.4 mg $GAEg^{-1}$, ABTS assay IC 50 of 0.72 $mgmL^{-1}$ and FRAP of 61.7 mg $GAEg^{-1}$ was recorded in MAE.	Gamage and Choo (2023) [12]
7	Comparison between Solid-liquid extraction and Microwave-assisted extraction	Distilled water Time - 40 min Temperature - 45 °C S-S - 1:20 (w/v) Time - 120 sec (MAE) Power - 300 W	Highest total monomeric anthocyanin content of 7925.29 $mgmL^{-1}$ was reported in Solid-liquid extraction Highest Yield of 73.17%, DPPH of 3.49 (μlm^{-1}), FRAP of 3.99 (μlml^{-1}), ABTS of 2.42 (μlml^{-1}), Phenolics of 29.78 mg $GAE100^{-1}$ and Flavonoids of 20.13 mg QE 100 g^{-1} was reported in MAE	Gomez *et al.*, (2022) [15]
8	Comparison between Conventional extraction (CE), Ultrasound assisted extraction (UAE), Microwave assisted extraction (MAE)	Water S/L ratio - 1:20 Temperature - 70°C Time - 45 min Ultrasonic power - 490 W Time - 56.88 min Temperature - 74°C Microwave power - 400 W Time - 5 minutes	Highest TAC of 39.90 mg L^{-1} and Extraction yield of 15.01% was reported in UAE compared to Microwave assisted extraction (MAE) and Conventional extraction	Thuy *et al.*, (2021) [49]
9	Ultrasonication	Ethanol 96% S/L ratio - 1:10 Time - 15 Frequency - 40 kHz	Highest yield of 71.03%, anthocyanins of 16.99 mg L^{-1} and pH of 6.69 was reported in UAE It also possessed high color change sensitivity, hence indicating its potential to be used as a natural pH indicator	Wijaya *et al.*, (2021)
10	Ultrasound assisted extraction (UAE)	Distilled water Time -45 min Temperature - 40°C L/S ratio - 10 mL/g Power level - 160 W	Highest anthocyanins recovery of 2.19 (mgcy-3-glu gDW^{-1}) was reported in UAE	Salacheep *et al.*, (2021) [36]
11	Comparison between Maceration and Ultrasound-assisted extraction (UAE)	Water S/L ratio - 1:20 Temperature - 60°C Time - 60 min Ultrasonic power - 560 W Temperature - room temperature	Highest Yield of 56.1% was reported in maceration Highest TAC of 4.2 mg CGE g^{-1} was reported in UAE	Ethel *et al.*, 2021
12	Ultrasonic-assisted Extraction	Water Time - 90 min Temperature - 60°C F/S ratio - 0.02 g ml^{-1} Frequency - 40 kHz pH condition - 7	Highest anthocyanins recovery of 1,425 g L^{-1} was reported in UAE	Syafa'atullah *et al.*, 2020 [45]
13	Microwave-assisted extraction (MAE)	Water S/L ratio - 1:20 Microwave power - 770 W Time - 1 min	Highest TAC of 30.9 mg CGE g^{-1} was reported in MAE compared to traditional method	Marsin *et al.*, 2020 [26]
14	Comparison between Ultrasound extraction and Conventional extraction	Doubled distilled water Temperature - 50°C, Time - 150min,S/L ratio - 1:15 Amplitude - 70%Power level- 240W, Frequency - 20kHz	Highest Phenolic content of 87.00 mg $GAEg^{-1}$ of drt weight, Flavonoid content of 29.00 mg QE g^{-1} of dry weight, Proanthocyanidins of 11.00 mg of CE g^{-1} of dry weight and Flavonols content of 10.00 mg QEg^{-1} of dry weight was reported in UAE compared to Conventional extraction	Mehmood *et al.*, 2019 [27]

Table 2: Studies on application of butterfly pea flower extract in food industry

S. No	Food product	Bio-activity Function	Major findings	References
1	Chicken breast meat	Blue butterfly pea flower extract used in smart packaging	Addition of the extract caused a significant decrease in the Tensile Strength and a significant increase in the maximum elongation at break, water solubility, and swelling values.	Asikkutlu and Yalcin 2025 [5]
2	Yoghurt and fermented milk with *Clitoria ternatea* anthocyanin extract	Natural antioxidant-rich blue colorant for dairy products	Anthocyanin extract had high color and antioxidant stability in yoghurt, but lower stability in fermented milk Higher antioxidant activity than control and spirulina in both products In yoghurt, color change (ΔE) was less with blue pea extract than spirulina during storage Blue pea anthocyanin is a better colorant for yoghurt, while spirulina performs better in fermented milk	Gamage *et al.*, 2024 [13]
3	Butterfly pea flower drink	Natural antioxidant-rich herbal beverage	Best quality achieved using fresh petals, boiling method, and lime juice added before extraction, hence it can be used as natural soft drink which posse's high antioxidants	Sofyan *et al.*, 2022 [43]
4	Sodium alginate film with *Clitoria ternatea*	Biodegradable freshness indicator for	Films with CTE improved strength, thermal stability, and light barrier properties	Santos *et al.*, 2022 [37]

	extract (CTE)	milk, shrimp, and pork	40% CTE films showed antibacterial activity against *E. coli* F40 film changed color with spoilage of milk (blue to purple) and meat (blue to green), making it suitable as a freshness indicator	
5	Yogurt enriched with blue pea flower extract (BPFE) from different milk types	Functional dairy product with natural antioxidants and color	Adding blue pea flower extract to yogurt increased antioxidant activity compared to plain yogurt Yogurt made with skim milk + blue pea flower extract had the highest antioxidant activity Blue pea flower extract contributed to natural blue-violet color and enhanced nutritional value	Sutakwa *et al.*, 2021 [44]
6	Muffins	Natural food color With antioxidant potential	Microcapsules of the flower showed good light and cold temperature stability (−20 °C to 4 °C) up to 21days When added to muffins, the microcapsules inhibited foodborne bacteria, showing potential as a natural bio-preservative for baked foods	Ab Rashid *et al.*, 2021
7	Instant powder drink from BPFE	Healthy drink with natural antioxidants	Made using vacuum concentration, sugar mixing, and drying at 60°C for 12 hours and stored for 28 days Antioxidant activity was stable	Marpaung *et al.*, 2020 [25]
8	Film made from *Clitoria ternatea* anthocyanin and sago polymer	Natural pH-sensitive sensor for detecting food spoilage	Responds to pH changes caused by microbial spoilage Successfully monitored spoilage in chicken breast samples under different conditions Safe, cost-effective, and biodegradable alternative to synthetic chemical dyes	Ahmad *et al.*, 2020 [2]
9	Cupcakes	Natural colorant and nutritional enhancer	Cupcakes baked with BP extract showed higher moisture and protein content than control Slight reduction in pH, ash, and lipid levels Anthocyanin content retained at 41.82% post-baking (2.58 mgL^{-1}) Overall, butterfly pea extract added both color and nutritional value to cupcakes	Thanh *et al.*, 2020 [48]
10	Beverage developed with blue pea flower extract, Stevia, and lime	Functional herbal drink with antioxidant potential	Optimized extraction (3 gL^{-1} at 59.6 °C for 37 min) using RSM Final drink had strong antioxidant activity via polyphenols and flavonoids High consumer preference for taste, aroma, color and stable without preservatives for 28 days	Lakshan *et al.*, 2019 [21]

Applications

Food Industry

Now-a-days, the food industry has great demand for natural colors with increasing consumer's awareness on natural products. The striking blue petals of the butterfly pea flower are commonly used as a natural coloring agent in Southeast Asian cooking. One of its unique properties of the flowers is its pH sensitivity, as the flowers change color from blue to pink or purple in acidic solutions. They lend a unique shade to various dishes, including glutinous rice and sweets. Moreover, the flowers are often steeped to create herbal teas that transform in color, from blue to pink or purple, when acidic ingredients such as lemon juice are added. This fascinating reaction attracts the consumers in food and beverage serving. The anthocyanin extracted from butterfly pea flowers have been studied for their role as natural pH-sensitive colorants in smart food packaging. These pigments change color based on pH levels, allowing for real-time monitoring of food freshness and quality. Much research was done regarding usage of anthocyanins from this flower for intelligent packaging with color indicator (Ahmad *et al.*, 2020) [2]. Also, the anthocyanin extract from this flower was used to monitor the freshness of sea foods (Vidana Gamage, 2021a) [50] pork and milk (santos *et al.*, 2022) [37]. The reviews on application of butterfly pea flower extract in food industry are presented in Table 2.

Agriculture

In agriculture, *Clitoria ternatea* L. is widely valued as a cover crop, especially in tropical climates. It plays a crucial role in soil enrichment by fixing atmospheric nitrogen, while its abundant biomass helps improve soil structure and health. Beyond its agricultural benefits, butterfly pea contributes to sustainable farming by suppressing perennial weeds and enriching the soil through nitrogen fixation. It is widely used as a drought-resistant pasture in arid and semi-arid regions (Oguis *et al.*, 2019) [33]. Research has shown that intercropping this plant with other crops can greatly enhance soil organic matter and nutrient levels, supporting sustainable farming methods. The plant offers green fodder throughout the year, making it particularly valuable during dry periods.

Medicine

In traditional Ayurvedic medicine, different parts of the butterfly pea plant have been used to treat disorders such as fever, inflammation, pain, and diabetes. Modern scientific studies have confirmed its medicinal properties, showing that plant extracts possess antioxidant, anti-inflammatory, analgesic, antipyretic, and antimicrobial effects (Sahu *et al.*, 2023) [35]. These beneficial qualities highlight its potential for use in health supplements and therapeutic applications. The high antioxidant content of butterfly pea flowers has made them a popular ingredient in skincare and haircare products. When applied topically, they are thought to improve skin hydration, boost elasticity, and reduce signs of aging. For hair, the plant's extracts may help strengthen follicles and slow graying, supporting overall hair health (Oguis *et al.*, 2019) [33].

Extracts from the flower, root, and leaves of *Clitoria ternatea* L. have demonstrated anti-inflammatory, analgesic, and antipyretic properties (Singh *et al.*, 2018; Devi *et al.*, 2003) [7]. Recent studies have also highlighted the potential of *Clitoria ternatea* L. leaf extracts in diabetes management (Chusak *et al.*, 2018 [6]; Kavitha *et al.*, 2018) [19]. Several studies have suggested that *Clitoria ternatea* L. exhibits nootropic properties. Those orally administered 300 mg/kg

of ethanolic extracts from *C. ternatea* roots or aerial parts demonstrated better memory retention in rats than the control group (Taranalli *et al.*, 2000) [47]. The flower's water extract contains phenolic compounds, flavonoids, and anthocyanins, which have been found to effectively prevent hemolysis and oxidative damage induced by 2,2′-azobis-2-methyl-propanimidamide dihydrochloride (AAPH) in canine erythrocytes (Phrueksanan *et al.*, 2014) [34]. Additionally, the extract demonstrated protective antioxidant effects against oxidative stress in skin cells exposed to H_2O_2 and UV radiation (Zakaria *et al.*, 2018) [54].

Conclusions

Butterfly pea (*Clitoria ternatea*) is a highly valued plant with nutritional, medicinal, and cosmetic applications. It is rich in anthocyanins, flavonoids, alkaloids, and peptides, offering potent antioxidant, anti-inflammatory, antimicrobial, neuroprotective, and antidiabetic benefits. Its flowers, seeds, and leaves contain bioactive compounds that support overall health and help reduce the risk of chronic diseases. The vibrant blue color of the flower is used as food colorant in bakery products, yoghurt and functional beverages. Compared to traditional method, non-thermal extraction methods such as Ultrasound-Assisted Extraction (UAE), Microwave Assisted Extraction are ideal for preserving heat-sensitive compounds such as anthocyanins and flavonoids in *Clitoria ternatea* L. Further research needs to be done to explored on novel technologies such as high-pressure processing, sub-critical water extraction to improve the extraction efficiency of bioactive compounds of butterfly pea flower. The pH sensitivity of the anthocyanin's can be well utilized in intelligent packaging for detecting food spoilage. Keeping in view of rare availability of natural blue colorant, its application in food industry needs to be expanded and explored.

Declaration of Competing Interest: The authors have no conflict of interest.

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