

CHAPTER 2 - LITERATURE REVIEW

2.1 Botanical Profile and Taxonomy of *Clitoria ternatea*

Clitoria ternatea, commonly known as Bunga Telang in Indonesia, is a multi-functional vine plant belonging to the family Fabaceae. Taxonomically, it is classified under the kingdom Plantae, division Magnoliophyta, class Magnoliopsida, and order Fabales, falling under the genus *Clitoria* and the specific species *Clitoria ternatea* L. The name is taken from Ternate Island in Maluku, where the plant was first collected and described by European taxonomists (Marpaung, 2020). In Indonesia it is widely grown as an ornamental vine in home gardens. Ethnobotanical records indicate that the plant's roots, leaves, seeds, and flowers have been used in traditional medicine for treating various illnesses and health problems (Purba, 2020). The petals are known for their richness in bioactive compounds with functional health benefits. These extracts have been studied by Indonesian researchers for their natural antioxidant, anti-inflammatory and antimicrobial properties (Purba, 2020).

2.1.2 Natural Food Colorants and Functionality

The global and local food industries have increasingly mentioned natural alternatives to synthetic food dyes to minimize the use of artificial additives in consumer products (Amchova, Kotolova and Ruda-Kucerova, 2015). In Indonesia, *Clitoria ternatea* is already used as a natural food colorant in both traditional culinary applications and modern commercial beverage development because its intense pigment serves as an effective, sustainable replacement for artificial dyes (Marpaung, 2020).

Clitoria ternatea is not the only plant used as such in Indonesia. People often turn to other local plants to get different colors. Roselle (*Hibiscus sabdariffa*) is used to give food and drinks a beautiful vibrant red or pink color (Mardiah et al., 2015). The creators use Pandan leaves (*Pandanus amaryllifolius*) for green color that will impact the rich green color and the famous sweet aroma to desserts and beverages (Wongpornchai, Sriseadka and Choonvisase, 2003).

These plants are not only attractive in terms of their appearance, but are also rich in antioxidants that aid in the safeguarding of the body against stress and inflammation (Purba, 2020). Such safety and history have resulted in the official approval of Indonesia's Food and Drug Authority, BPOM (under Regulation No. 22 of 2023) for the *Clitoria ternatea* extract to be used as a legal and safe natural colorant in daily food and beverage products (Badan Pengawas Obat dan Makanan, 2023).

2.3 Chemical Composition and Color Stability

2.3.1 Definition and Structure of Anthocyanins

Anthocyanins are a large group of water-soluble pigments found in the vacuoles of plant cells. They are responsible for the vibrant red, purple, and blue colors seen in many fruits, vegetables, and flowers. Chemically, anthocyanins belong to the flavonoid family and possess a basic flavylum cation core structure. This core structure contains multiple hydroxyl groups and attached sugar molecules, making the pigments highly hydrophilic, meaning they dissolve easily in water-based solutions.

2.3.2 Anthocyanin Profile in *Clitoria ternatea*

The deep blue and purple colors of *Clitoria ternatea* (butterfly pea) are attributed to a new class of highly stable anthocyanins termed ternatins (Terahara et al., 1998). Structurally, they are all based on a chemical backbone called delphinidin (specifically delphinidin 3,3',5'-triglucosides). (see Figure 2.1).

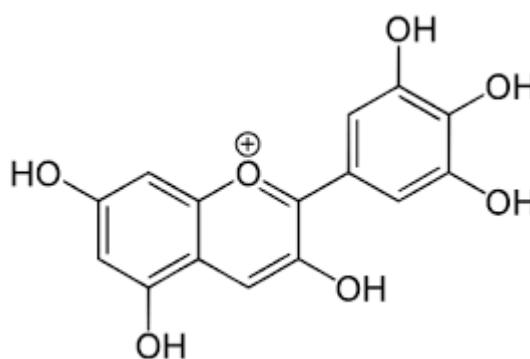


Figure 2.1 Core chemical structure of the delphinidin aglycone backbone

The special about the anthocyanin profile of this flower is that these ternatin molecules are modified with attached malonyl and coumaroyl groups that form a chemical protective shield around the colorant. This complex acylation prevents the color from easily degrading under heat or light situations, and is much more stable than the simple and delicate anthocyanins found in fruits such as berries or grapes. However, the color can still degrade over time under certain conditions (such as storage at neutral pH 7) mainly through the gradual loss of these protective acyl groups called deacylation process (Marpaung et al., 2017).

2.3.3 Color Stability

Anthocyanins are natural pH indicators and their chemical structure changes based on the pH of their environment. Under highly acidic conditions they convert to a stable form which is a bright reddish pink colour. When the liquid becomes neutral or slightly alkaline, the molecules again change their form producing a purple structure or becoming colourless.

Environmental factors such as temperature, light, oxygen and storage conditions influence the longevity of these pigments. Previous research on *Clitoria ternatea* indicated that the extract had a more intense colour as well as healthy compounds under acidic conditions (pH 4 to 5), and were stable for up to two months at room temperature and six months in the fridge (Angriani, 2019). On the other hand, at a neutral pH 7, the blue color degrades much faster. This happens because the blue color slowly loses its natural protective shield over time, and any trapped air or oxygen inside the packaging makes it degrade even faster (Marpaung et al., 2017).

2.4 Wild Type vs. Mauve Type

In Indonesia, *Clitoria ternatea* has specific genetic variations that impact the visual appearance of its petals. The most common variety is the Wild Type, which produces a deep, rich blue pigment. On the other hand, the natural genetic mutations have produced rarer variants, such as the light pink Mauve mutant flower.

The colour differences of these two flowers are due to genetic variations that change the natural enzymes that produce the colour pigments of the plant (Kazuma et al., 2003). This shift changes the ratio of the flower's signature blue pigment delphinidin relative to other pigments such as cyanidin or pelargonidin, which in turn affects the light color of the flower petals (Lee et al., 2011). These unique color changes, provide new possibilities for developing food and beverage products, as shown in the image below.



Figure 2.2 Visual color variations of *Clitoria ternatea* petals: Mauve Type mutant (top) and dominant blue Wild Type (bottom).

2.5 Natural Colorants in Functional Beverages

Clitoria ternatea as a functional beverage can be compared to other high-antioxidant plants that are often used in Indonesia as a food colorant such as *Ipomoea batatas* (purple sweet potato), *Hibiscus sabdariffa* (roselle), *Camellia sinensis* (green tea), and *Curcuma longa* (turmeric). Green tea contains high levels of healthy catechins and

roselle is rich in vitamin C, but these two plants are very sensitive to the manufacturing processes. For example, the bright red pigments of roselle are highly sensitive to heat and the drink will turn brown and lose its color during standard pasteurisation process (Cisse et al., 2012).

In contrast, the ternatin molecules that are found in *Clitoria ternatea* are resilient and remain stable under high temperatures (Terahara et al., 1998). This natural structural strength also helps the drink keep its vibrant blue colour and antioxidants. This makes butterfly pea flower a much more reliable and consistent option for commercial beverage production compared to other botanical ingredients (Marpaung, 2020).

2.6 Consumer Acceptance of *Clitoria ternatea* Beverages

2.6.1 Sensory Properties and the "Earthy" Limitation

Functional drinks are all about combining health benefits with great taste. The main challenge with using pure Wild Type *Clitoria ternatea* extract is its unique taste profile which often gives a strong earthy taste which can be unappealing to consumers. However, the Mauve variant has a much softer flavour and an attractive soft pink color, but it doesn't have the strong visual punch like the wild type version. Natural flavour modifiers are used by food processors to overcome this limitation of sensory. Lakshan et al. (2019) showed that the addition of pure butterfly pea extract with an acid modifier (e.g., lime juice) and a natural sweetener (e.g., Stevia) increases consumer preference scores. Those ingredients can conceal the raw herbal notes and the acidity makes the color change in a visually stunning way.

2.7 Flower Blending Ratios in Product Formulation

The commercialization of *Clitoria ternatea* has rapidly evolved from *jamu* (herbal medicine) to functional beverages in urban markets (Purba, 2020). Finding the perfect blend of Wild Type and Mauve flowers is a great way to maximise consumer interest.

Product developers can combine the rich antioxidant properties of the Wild Type with the softer visual profile of the Mauve mutant by combining these two cultivars (Md.

Bakhtiar Lijon, 2017). This natural blending approach works beautifully in addition with ingredients like lychee and mint syrups to create a unique pastel-hued drink that delivers on exactly what modern lifestyle consumers expect.

2.8 Previous Studies

A systematic selection of recent literature was performed to establish a validated baseline for extraction kinetics, chemical tracking and sensory evaluation of *Clitoria ternatea* formulations. Below is an empirical matrix displaying six major peer-reviewed papers published after 2020 that directly parallel the core methodologies of this thesis.

The scientific limits of hot-water extraction parameters, colorimetric calculations and consumer testing are defined in these papers. The existing studies are then used to map known data for the traditional wild blue variety giving a clear comparison to which the newly isolated Mauve mutant and its unique blended formulations can be compared.

Table 2.1 Previous Study of *Clitoria ternatea* Physicochemical Properties and Sensory Evaluations

Author	Focus	Variables Analyzed	Key Findings
Lakshan <i>et al.</i> (2019)	Formulation, optimization, and sensory analysis of a functional beverage using butterfly pea extract.	pH, total polyphenolic content, total antioxidant capacity, and 9-point hedonic scale scores (evaluating color, flavor, taste, and overall acceptability using Stevia and lime juice).	Sweeteners and acids are effective in masking the unappealing, earthy taste of raw extracts and still maintain high antioxidant properties, leading to an improvement in flavour acceptance by consumers.

(Pasuka monset, Kwon and Adisakwattana, 2016)	Stabilizing and protecting butterfly pea flower polyphenols using an alginate-based gel network.	Microencapsulation efficiency, structural pigment retention, total phenolic content, and antioxidant activity under simulated gastrointestinal stress.	The physical barrier formed by trapping the extract within a gel network protects the fragile anthocyanins from rapid chemical breakdown, justifying its use in solid layers, e.g., grape jelly.
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Shiau <i>et al.</i> (2023)	Evaluating the explicit impact of natural food colorants on consumer visual attraction and product liking.	Phytochemical distribution, colorimetric properties (L*, a*, b* values), and targeted hedonic sensory panel scores isolating visual appearance liking from raw flavor attributes.	Higher extract concentrations yield significantly better appearance and color preference scores. Higher concentrations of the extracts result in much improved appearance and color preference scores.
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Marpaung <i>et al.</i> (2017)	Laboratory tracking of the chemical degradation and structural color changes of butterfly pea anthocyanins.	First-order reaction degradation kinetics, half-life (t _{1/2}) calculations, and spectrophotometric light absorbance metrics measured across specific visible	This paper establishes a clear timeline for color fading and provides the exact baseline numbers needed to measure pigment breakdown.
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$$\text{wavelengths } (A_{628}, A_{580}, A_{550}).$$

This research is built on the studies listed in the table above, with each paper addressing a piece of the puzzle that correlates with one another. Marpaung et al. (2017) follow how that color fades over time at a steady and predictable rate. Pasukamonset et al. (2016) shows that trapping these colors in a gel layer creates a protective shield that prevents them from breaking down too quickly.

On the consumer side, Lakshan et al. (2019) shows that sweeteners and acids added to the raw flower successfully conceal the earthy flavour of the raw flower. However, there are still limitations in the current literature. These characteristics have been studied separately by scientists and until now we have not been able to see how they all work together. We still do not know how the fading colors, the protective gel, and the taste modifiers all work together when they are mixed into a single, complex drink.

2.8.1 Identification of the Research Gap

However, there is a big gap in the previous research, which only studies about the traditional blue flower. The new developed mauve mutant is not studied for its color traits, pigment content and antioxidants. No one has tried to combine the blue and mauve flowers together in a beverage drink with grape jelly, lychee syrup and mint syrups.