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A Study On Butterfly Pea Flower : Anthocyanin Extraction And It's Uses In Dye Industry

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Abstract: *Clitoria ternatea,* or butterfly pea, produces edible blue flowers rich in anthocyanins, especially ternatins, which give the petals their vibrant blue color. Anthocyanins were extracted from 5.301 g of fresh petals using hot water, showing good thermal and storage stability. Phytochemical analysis confirmed the presence of steroids, tannins and flavonoids, indicating its potential in dye industries. Cotton fabric samples were dyed with butterfly pea flower extract in combination with mordants such as alum, copper sulfate, ferrous sulfate, and sodium hydroxide. Copper sulfate and ferrous sulphate proved most effective in fixing the dye.

***Index Terms* -** Butterfly pea, anthocyanins, steroids, tannins, flavonoids, color fastness.

I. Introduction

Clitoria ternatea L., commonly known as butterfly pea and belonging to the Fabaceae family, is a plant of significant interest due to its wide range of applications across various industries, particularly in medicine, food, cosmetics, and textile dyeing (Siti Azima et al., 2017). The plant's flowers are rich in anthocyanins—natural water-soluble pigments responsible for vivid blue to purple coloration, which are not only visually appealing but also offer multiple health benefits, including antioxidant, antimicrobial, anti-inflammatory, antidiabetic, and cytotoxic properties (Vidana Gamage GC et al., 2021).

The primary anthocyanin in butterfly pea is delphinidin, a compound known for its intense coloration and color-changing properties in response to pH variations (Chusak, Laokuldilok, & Kerdchoechuen, 2021). Under acidic or neutral conditions, the extract shifts from blue to shades of pink or purple, making it an attractive natural dye and pH indicator.

Anthocyanins, which exist in more than 540 known forms, are found in various parts of plants including flowers, fruits, stems, and roots. Notable sources include raspberry, cherry, blood orange, and aubergine. Their increasing demand is driven by the global shift towards sustainable, non-toxic, and health-promoting natural products. As a result, butterfly pea flower extract is gaining popularity as an organic and safe alternative to synthetic dyes in the food, pharmaceutical, and textile industries. The extract has also been utilized in hair coloring and cosmetic products due to its rich pigmentation and beneficial phytochemicals such as flavonoids, tannins, steroids, glycosides, saponins, and triterpenoids (Jaiswal, Kadam, Gangurde, Mouraiya, & Dhokane, 2023).

To achieve optimal dye adherence and enhance color fastness, several mordants are employed during the dyeing process. These include alum (potassium aluminum sulfate), which is commonly used with natural dyes; iron (ferrous sulfate), known to darken shades and improve durability; tannic acid, frequently used with natural fibers; copper sulfate, which modifies dye hues; and sodium carbonate (soda ash), often used in reactive dyeing to fix colors effectively (Botanical Colors, n.d). The interaction of these mordants with anthocyanins plays a crucial role in determining the final shade and color fastness (characterizes a material's color's resistance to fading or running) properties of the dyed fabric (Botanical Colors, n.d).

II MATERIALS & METHODS :

MATERIALS:

Sr. No	Type	Particular	Quantity
1.	Plant material	Fresh butterfly pea flower petals (Figure 1)	5.923 g (about 20 flowers)
2.	Chemicals and Reagents	• Chloroform • Concentrated sulfuric acid • Glacial acetic acid • 0.1% Ferric chloride • Alcohol • Distilled water • 10% Sodium hydroxide • Concentrated hydrochloric acid	2ml 2ml 2ml 2-3 drop 2-3 drop 500ml 2ml 2ml
3.	Solvent	Water (for dye extraction)	500ml
4.	Equipment	• Testtubes • Burner • Cotton cloth • Strainer • Glass jars (dye collection/storage) • Beakers • Gas supply	8 1 4 pieces 1 4 5
5.	Heating and Cooling Devices	• Water bath (extraction) • Refrigerator (dye storage)	1 1
6.	Protective Gear	Lab coat and gloves (safety)	2
7.	Measuring Instruments	• Pipettes • Weighing balance	10 1
8.	Storage Container	Glass jars (sample storage)	5
9.	Mordent	• Alum • Copper sulfate • Sodium carbonate • Ferrous sulfate	5.923g 1g 0.577g 0.567g

METHODS :

1.Extraction of Dye

Fresh butterfly pea flowers (*Clitoria ternatea*) were collected, cleaned thoroughly under running tap water to remove surface impurities, and then rinsed with distilled water. For the aqueous extraction, 5.093 grams of the fresh butterfly pea petals were weighed using an analytical balance and transferred into a beaker for boiling. The mixture was stirred gently and maintained at 100°C temperature for 15 minutes for the extraction of anthocyanins and other water-soluble phytochemicals. After the extraction period, the solution was allowed to cool to room temperature and subsequently filtered to separate the solid residue. The filtrate, representing the butterfly pea flower dye extract (Figure 2), was collected and stored in glass jars at 4°C until further analysis (Sangeetha, Manonmani, & Janani, 2024).

2.Phytochemical Analysis

Qualitative tests were conducted on the dye extract to detect various phytochemical constituents (Nurhayati et al., 2024) :

a) Test for steroids: Take 2ml of dye extract dissolved in 2ml of chloroform and add 2ml concentrated sulphuric acid in a test tube, red color produced in the lower chloroform layer indicates the presences of steroids.

b) Test for Glycosides: Take 2ml of the dye extract and combine with 2ml of glacial acetic acid, add 1 drop of ferric chloride, 1ml of concentrated sulfuric acid, and thoroughly mixed. The presence of glycosides is indicated by a brown color appearance.

c) Test for phenols: Take 0.5ml of extract and a few drops of alcohol and add few drops of ferric chloride. Shake well till the appearance of greenish-yellow color, which indicates the presence of phenol.

d) Test for tannin: Take 0.5ml of the extract, mix it with 20ml of distilled water and boil for some time and then add few drops of 0.1% ferric chloride, mix well till the appearance of brownish-green color which indicates the presence of tannin.

e) Test for Flavonoids: Take 0.5ml of extract and mix it with 10% sodium hydroxide. Greenish-brown color indicates the presence of flavonoids.

f) Test for saponin: Take 0.5ml of extracts with a small amount of distilled water. The appearance of frothing will indicate the presence of saponin.

g) Test for quinine: Take 0.5ml of extract, mix it with a few drops of concentrated hydrochloric acid. Appearance of green color indicates the presence of quinine.

h) Test for terpenoids: Take 2 ml of extract and combine with 2ml of chloroform, add a few drops of strong sulfuric acid .The emergence of light orange color

3.Mordanting Procedure for Dye-Mordant Interaction :

Four mordants were used in the dyeing process: alum (5.923 g), copper sulfate (1 g), sodium carbonate (0.577 g), and ferrous sulfate (0.567 g). An accurate weight of each mordant was taken separately in the preparation. For every mordant treatment, 100 mL of the dye extract was boiled together with the corresponding mordant to allow proper dissolution and reaction between the dye and the mordant. This boiling process enhanced the fixation of dye compounds and mordant-dye bonding, which is required to develop color fastness and intensity on the substrate.

4.Dyeing Process:

Cotton fabric samples were immersed in the dye solution with the mordant and allowed to stand for 15 minutes (Figure 3). The fabric samples were then allowed to cool down, then gently squeezed to remove excess liquid, and air-dried. The clothes were washed under tap water after 24 hours to test the fixation of the dye i.e color fastness (Sangeetha et al., 2024; Nguyen et al., 2024).

III RESULTS

Phytochemical analysis of the butterfly pea flower extract confirmed the presence of steroids, tannins, and flavonoids. Glycosides, phenols, saponins, quinine, and terpenoids were not found in the plant extract (Table 2).

The effect of different mordants on dye fixation was investigated with cotton fabric treated with butterfly pea (*Clitoria ternatea*) flower extract. The results (Figure 4) showed differences in color variation and color fastness based on the used mordant as follows :

a) Alum: Initially, the dye shifted from blue to purple due to the pH sensitivity of anthocyanins. Still, the color washed out entirely after drying and rinsing, showing poor fixation and narrow applicability as a mordant.

b) Copper sulfate: No color change was visible; the dye was still blue on the cloth. The treated cotton fabric samples had good color fastness, indicating copper sulfate is an effective mordant for stabilizing butterfly pea dye on materials.

c) Sodium carbonate: The dye turned yellow due to the alkaline pH environment, but most of the color was removed during drying and washing. This indicates poor dye retention and poor mordanting property.

d) Ferrous sulfate: The blue color turned purple and resulted in a brown shade on the fabric. The mordanted cloth retained the dye with good color fastness even after washing, indicating ferrous sulfate as an effective and strong mordant.

Among the mordants tested, copper sulfate and ferrous sulfate were seen to have good possibilities for natural dyeing with butterfly pea extract due to their improved color fixation and color fastness. However, alum and sodium carbonate were seen to have weak interaction with the dye and are not recommended for textile dyeing.

IV DISCUSSION

The findings of this work show the potential of *Clitoria ternatea* flower extract as a natural dye source owing to its phytochemical content and response to several mordants. Phytochemical analysis further confirmed the presence of steroids, tannins, and flavonoids, which have been shown to be accountable for color strength and dye stability by complexing with the textile fibers and metal ions (Ali et al., 2017; Samanta & Agarwal, 2009). The absence of other secondary metabolites such as glycosides, phenols, and terpenoids reflects that the dyeing efficiency is primarily due to the existence of anthocyanins, in the form of flavonoids, as water-soluble pigments that confer the characteristic blue to purple hue (Nguyen et al., 2024).

The interaction between the dye and various mordants showed varied outcomes in terms of color alteration and color fastness. Alum, although used traditionally for natural dyeing, proved to be relatively ineffective for butterfly pea flower extract. The blue to purple color change is consistent with the documented pH sensitivity of anthocyanins (Rodriguez-Saona & Wrolstad, 2001); however, the total color loss when washed showed poor dye-fiber bonding when alum alone is used.

Alternatively, copper sulfate demonstrated exceptional color fastness and dye retention without any significant variation of the original blue color. This indicates high coordination between copper ions and flavonoid components of the dye, which provides stability in the context of cotton fibers (Bechtold & Mussak, 2009). Similarly, ferrous sulfate gave a brown shade with excellent color fastness due to stable iron-flavonoid complexes that are bound firmly to the substrate, similar to what was noted in previous research involving iron as a mordant (Gulrajani, 2010).

Contrary to this, sodium carbonate, an alkaline mordant, exhibited a vivid color change to yellow, which faded upon washing later. This is caused by degradation or conversion of anthocyanins under high pH conditions, and thus sodium carbonate is unfit for dye color retention on cotton substrates (Kong et al., 2003).

Typically, copper sulfate and ferrous sulfate proved to be the optimum mordants for color fixation and color fastness when used in conjunction with butterfly pea flower extract. The findings are in conformity with previous research that emphasizes the importance of metal salts as catalysts in dye-metal-fiber complex formation to enhance fastness properties (Shahid et al., 2013). The ineffectiveness of sodium carbonate and alum, on the contrary, emphasizes the importance of selecting effective mordants to create desired dyeing effects using natural dyes.

These findings support the use of plant-based, eco-friendly dyes and signal that with the right mordants, butterfly pea flower extract can serve as a green alternative to synthetic dyes used in the textile industry.

V CONCLUSION

Extracting dye from butterfly pea flowers presents a promising approach to developing natural colorants with multifunctional benefits. By optimizing extraction methods and understanding the dye’s properties, industries can harness this resource for sustainable applications.

VI FIGURES & TABLES :

Figure 1 : butterfly pea flower

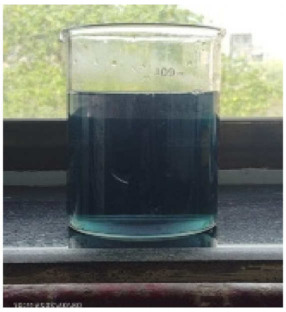

Figure 2 : extracted dye

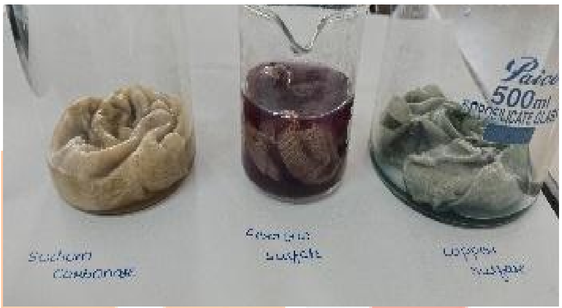

Figure3 : comparison of dye fixation using different mordants: sodium carbonate(1st beaker, ferrous sulfate(2nd beaker) and copper sulfate(3rd beaker)

Figure 4 : dye fastness on fabric samples after washing : 1st fabric(sodium carbonate), 2nd fabric(copper sulfate), 3rd fabric(ferrous sulphate) and 4th fabric(alum)

Table 2 : phytochemical analysis

TEST	RESULT
Steriods	Positive
Glycosides	Negative
Phenols	Negative
Tannin	Positive
Flavonoids	Positive
Saponin	Negative
Quinine	Negative
Terpenoids	Negative

E) Acknowledgment

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