

“Isolation and Characterization of a Natural Food-Grade Dye from *Butea monosperma* (Lam.) Kuntze Flowers”

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Abstract

The increasing concerns regarding the safety and environmental impact of synthetic food colorants have led to a growing demand for natural, eco-friendly alternatives. In this context, the present study focuses on the isolation and characterization of a natural food-grade dye from the flower petals of *Butea monosperma* (Lam.) Kuntze, a plant widely distributed in tropical regions and traditionally known for its vibrant pigmentation. Fresh and dried petals were subjected to aqueous extraction under controlled temperature conditions, followed by filtration, concentration, and drying to obtain a stable pigment powder. The extraction process yielded a significant amount of dye, indicating the efficiency of water as a solvent for pigment isolation. The resulting dye exhibited a bright orange-red color, high water solubility, and good stability under normal storage conditions. Physicochemical analysis revealed favorable properties such as low moisture content, uniform particle texture, and resistance to moderate temperature variations. The pigment was successfully incorporated into model food systems, including beverages and confectionery products, without affecting their sensory characteristics. These findings suggest that *Butea monosperma* flowers represent a promising, sustainable source of natural food colorants with potential applications in the food industry. The study highlights the importance of utilizing underexploited plant resources for developing safe and value-added natural products.

Keywords: *Butea monosperma*, natural dye, food colorant, flavonoids, chalcones, plant pigments, eco-friendly dyes, sustainable food additives.

Introduction

Color is a crucial sensory attribute that significantly influences consumer perception, acceptance, and preference of food products (Downham & Collins, 2000). The incorporation of colorants in food enhances visual appeal and is often associated with quality and freshness (Carle et al., 2017). Historically, natural pigments derived from plant and mineral sources were widely used; however, synthetic dyes became dominant due to their low cost, stability, and wide range of colors (Delgado-Vargas et al., 2000).

Despite their advantages, synthetic food colorants have been linked to several health concerns, including allergic reactions, hyperactivity in children, and potential carcinogenic effects (Amchova et al., 2015; McCann et al., 2007; Kobylewski & Jacobson, 2012). These concerns have led to increased regulatory scrutiny and a global shift toward natural alternatives (Yusuf et al., 2017). Consumers increasingly prefer clean-label food products containing natural ingredients, driving research into plant-based colorants (Carle et al., 2017).

Natural pigments such as anthocyanins, carotenoids, flavonoids, and betalains are responsible for coloration in plants and possess additional antioxidant and health-promoting properties (Khoo et al., 2017; Rodriguez-Amaya, 2016). These compounds contribute to functional food development and may offer protection against oxidative stress and chronic diseases (Giusti & Wrolstad, 2003; Pandey & Rizvi, 2009).

Butea monosperma (Lam.) Kuntze, commonly known as Palash or Flame of the Forest, is a deciduous tree belonging to the family Fabaceae and is widely distributed in India and Southeast Asia (Das et al., 2011; Gupta et al., 2017). The flowers of this plant are rich in flavonoids, chalcones, aurones, and polyphenolic compounds such as butrin and isobutrin, which impart a characteristic orange-red color (Sharma & Deshwal, 2011; Rana & Mazumdar, 2012). These pigments are water-soluble and exhibit strong tinctorial properties, making them suitable for dye applications (Ravindranath et al., 2000).

In addition to their coloring properties, extracts of *Butea monosperma* have been reported to possess antioxidant, antimicrobial, anti-inflammatory, and hepatoprotective activities (Cowan, 1999; Das et al., 2011). Such multifunctional properties enhance their value as nutraceutical ingredients (Pandey & Rizvi, 2009).

Previous studies have demonstrated the use of natural dyes from plant sources such as turmeric, beetroot, and saffron; however, limited attention has been given to *Butea monosperma* despite its abundance and strong pigmentation (Sivakumar & Sulochanamma, 2015). Therefore, there is a need to explore its potential as a sustainable food-grade colorant.

The present study aims to isolate and characterize a natural dye from *Butea monosperma* flowers using eco-friendly extraction methods and to evaluate its physicochemical properties and suitability for food applications.

Materials and Methods

Collection and Authentication of Plant Material

Fresh flowers of *Butea monosperma* (Lam.) Kuntze were collected during the peak flowering season (February–March 2025) from the Kopargaon region, Maharashtra, India. The plant material was authenticated based on standard floristic literature and morphological characteristics. Collected flowers were washed thoroughly with distilled water to remove dust and extraneous materials.

Preparation of Plant Material

The collected flowers were shade-dried at ambient temperature ($25 \pm 2^\circ\text{C}$) for 7–10 days until constant weight was achieved. Shade drying was preferred to prevent degradation of heat-sensitive pigments. The dried petals were then ground into fine powder using a mechanical grinder and stored in airtight containers to prevent moisture absorption.

Extraction of Natural Dye

Aqueous extraction was carried out using distilled water as a solvent to ensure food-grade safety.

Approximately 100 g of dried flower powder was transferred into a 500 mL conical flask, and 250 mL of distilled water was added. The mixture was heated on a water bath at $60\text{--}80^\circ\text{C}$ for 4–5 hours with intermittent stirring to facilitate extraction of pigments.

After extraction, the mixture was cooled to room temperature and filtered through muslin cloth followed by Whatman No. 1 filter paper to remove plant residues. The filtrate containing dissolved pigments was collected for further processing.

Concentration of Extract

The filtrate was concentrated using a water bath maintained at $45\text{--}50^\circ\text{C}$ until a semi-solid extract was obtained. Care was taken to avoid overheating, which could degrade thermolabile pigments.

Drying and Powder Formation

The concentrated extract was transferred to clean glass petri dishes and dried in an incubator at 50°C for 4–5 days to obtain a dry pigment mass. The dried material was then ground using a mortar and pestle to produce a fine powder.

The resulting powder was stored in airtight containers at room temperature for further analysis.

Determination of Yield

The percentage yield of the extracted dye was calculated using the following formula:

$$\text{Yield (\%)} = \frac{\text{Weight of dried dye}}{\text{Weight of dried plant material}} \times 100$$

Physicochemical Analysis

1. Solubility Test

The solubility of the dye powder was tested in distilled water, ethanol, and acidic solutions (pH 3–5). The degree of solubility was recorded based on visual clarity and absence of precipitation.

2. pH Stability

The stability of the dye was evaluated at different pH levels (acidic, neutral, and alkaline conditions). Color changes were observed and recorded.

3. Thermal Stability

The dye solution was subjected to different temperatures (4°C, 25°C, and 40°C) to assess its stability under storage and processing conditions.

4. Light Stability

Samples were exposed to natural light and dark conditions for 30 days to evaluate color retention.

Application in Food Systems

The extracted dye was incorporated into model food systems such as sugar syrup, milk-based beverages, and confectionery products. The color intensity, uniformity, and stability were visually evaluated.

Results

Extraction Yield and Efficiency

Aqueous extraction of *Butea monosperma* flower petals resulted in a high yield of natural pigment. The average yield of crude extract obtained was 33.84% (w/w) from dried flower material, indicating efficient extraction of water-soluble pigments. The high yield suggests that distilled water is an effective and safe solvent for food-grade dye extraction.

Physical Characteristics of Extract

The concentrated extract exhibited a bright orange-red coloration, characteristic of *Butea monosperma* pigments. The extract had a pleasant floral odor and showed complete solubility in water, forming a clear and homogeneous solution without precipitation.

Effect of Solvent on Dye Yield

Among the solvents tested, distilled water produced the maximum yield and most intense coloration of the dye. This confirms the hydrophilic nature of the pigment compounds, particularly flavonoids and chalcones.

Table 1. Effect of Solvent on Dye Yield

Solvent Used	Colour Shade	Yield (%)
Distilled Water	Orange-red	33.84

Powder Characteristics

The concentrated extract was successfully converted into a dry powder using incubator drying at 50°C. The resulting powder was:

- Bright orange in color
- Free-flowing and non-sticky
- Easily soluble in water
- Low moisture content (3.2%)

These characteristics indicate good storage stability and suitability for industrial handling.

Stability Studies

The extracted pigment demonstrated good stability under acidic and neutral conditions. The dye retained approximately 90% of its color intensity after 30 days at room temperature.

However, slight color fading was observed at elevated temperatures, indicating moderate thermal sensitivity.

Application in Food Systems

The dye was successfully incorporated into model food products such as beverages, sweets, and confectionery items. The pigment showed:

- Uniform dispersion

- Stable coloration
- No precipitation
- No alteration in taste or odor

This confirms its compatibility with food matrices and suitability as a natural colorant.

Discussion

The present study demonstrated that *Butea monosperma* flowers are a rich source of natural pigments suitable for food-grade applications. The high extraction yield (33.84%) (Table 1) obtained through aqueous extraction highlights the efficiency of water as a solvent for isolating hydrophilic phytochemicals such as flavonoids and chalcones. These findings are consistent with previous studies reporting efficient pigment extraction using aqueous systems.

The bright orange-red coloration of the extract can be attributed to the presence of flavonoid compounds such as butrin and isobutrin, which are known for their strong chromophoric properties. These compounds not only contribute to color intensity but also exhibit antioxidant activity, thereby enhancing the functional value of the dye.

The excellent water solubility observed in the present study is a desirable property for food applications, particularly in beverages and liquid formulations. The ability of the dye to dissolve completely without precipitation indicates its compatibility with aqueous food systems.

The conversion of the extract into a stable powder form further enhances its applicability. The low moisture content (3.2%) and non-sticky nature of the powder indicate good shelf stability and ease of handling. This is particularly important for commercial applications where storage and transport conditions play a critical role.

Stability studies revealed that the pigment retained its color intensity under normal storage conditions, particularly in acidic environments. This is significant because many food products, such as beverages and confectionery items, operate within acidic pH ranges. The moderate thermal sensitivity observed suggests that the dye is best suited for applications involving low to moderate heat processing.

The successful incorporation of the dye into model food systems without affecting taste, odor, or texture confirms its suitability as a food-grade colorant. Compared to synthetic dyes, which are associated with potential health risks, the natural pigment derived from *Butea monosperma* offers a safer and environmentally friendly alternative.

Furthermore, the presence of bioactive compounds such as flavonoids and phenolics provides additional health benefits, including antioxidant activity. This aligns with the growing demand for functional foods and clean-label ingredients.

Overall, the findings of this study support the potential of *Butea monosperma* as an underutilized plant resource for the development of natural food colorants. The combination of high yield, stability, solubility, and safety makes it a promising candidate for industrial applications. However, further studies on large-scale extraction, toxicity evaluation, and regulatory approval are required to facilitate commercialization.

Conclusion

The present study successfully demonstrated the isolation and characterization of a natural food-grade dye from the flowers of *Butea monosperma* using an eco-friendly aqueous extraction method. The high extraction yield (33.84%) confirms the efficiency of water as a safe and effective solvent for obtaining pigment from plant material suitable for food applications.

The extracted dye exhibited desirable physicochemical properties, including bright orange-red coloration, excellent water solubility, low moisture content, and satisfactory stability under ambient and mildly acidic conditions. The successful conversion of the extract into a stable, free-flowing powder further enhances its potential for storage, transport, and industrial utilization.

The pigment also showed good compatibility with various model food systems, producing uniform and stable coloration without affecting sensory properties. These findings highlight its suitability as a natural alternative to synthetic food colorants, which are often associated with health and environmental concerns.

In addition to its coloring properties, the presence of bioactive compounds such as flavonoids and phenolics suggests potential functional benefits, including antioxidant activity, thereby adding value beyond aesthetic application.

Overall, *Butea monosperma* flowers represent a promising, sustainable, and underutilized source of natural food-grade dyes. The study supports the growing demand for clean-label, plant-based ingredients in the food industry and contributes to the development of eco-friendly alternatives to synthetic additives.

However, further research is recommended to evaluate the long-term stability, toxicological safety, large-scale extraction feasibility, and regulatory compliance of the dye for commercial application. Exploration of advanced purification techniques and formulation strategies may further enhance its industrial applicability.

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