

# Optimising Natural Dyeing of Cotton with *Butea Monosperma* Through Anodic Pretreatment and Eco-Friendly Auxiliaries

Yanisa Komonsilichok<sup>a</sup>, Piyanut Jingjit<sup>b,\*</sup>

<sup>a</sup>*Rajamangala University of Technology Lanna, Huay Kaew Road, Muang, Chiang Mai, 50300, Thailand*

<sup>b</sup>*Rajamangala University of Technology Thanyaburi, Rangsit-Nakorn Nayok Road, Pathum Thani, 12110, Thailand*

---

## Abstract

This study investigates the combined effect of anodic pretreatment and varying auxiliary formulations on the dyeing performance of cotton fabric using a natural dye extracted from *Butea monosperma* flowers. While past studies have examined the role of mordants and pH modifiers in natural dyeing, limited attention has been given to how auxiliary systems interact with electrochemically modified fabrics to influence colour yield and fastness performance. This research addresses that gap by evaluating how anodically pretreated cotton responds to common dyeing auxiliaries—sodium chloride (NaCl), potassium aluminium sulfate (alum), sodium carbonate (Na<sub>2</sub>CO<sub>3</sub>), and calcium oxide (CaO)—in terms of shade development, chromatic richness, and durability.

Using the CIE Lab colour system, significant colour variations were observed across all treated specimens (2–7) compared to the salt-only control (specimen 1).  $\Delta E$  values ranged from 12.49 to 19.95, with the highest chromatic shift seen in the NaCl + alum sample, which produced a vivid orange hue with enhanced redness and yellowness. Combinations of alum and alkalis yielded deeper, more saturated shades, while alkali-only formulations produced earthier tones with moderate lightness. These outcomes highlight the synergistic effect of anodic surface activation and auxiliary chemistry on improving dye-fibre interactions.

Fastness tests, conducted according to ISO 105-C10 and ISO 105-X12 standards, revealed moderate washing durability (colour change ratings of 3 to 4) and good rubbing fastness (ratings up to 4). Specimens treated with mordants and alkalis generally exhibited improved fixation and reduced staining, whereas anodic treatment enhanced surface adhesion of the dye.

This study demonstrates a promising, low-impact approach to improving natural dye uptake and fastness on cotton fabric by integrating anodic pretreatment with accessible auxiliary systems. The findings support the development of sustainable, decentralised dyeing processes using locally available plant waste, with particular relevance for rural craft and textile communities seeking eco-friendly alternatives to synthetic dyes.

*Keywords:* *Butea monosperma*, natural dyeing, anodic pretreatment, cotton fabric, dye auxiliaries, colour fastness, sustainable textiles, rural textile innovation

---

\*Corresponding author.

*Email address:* piyanut@rmutt.ac.th (Piyanut Jingjit).

## 1 Introduction

In many tribal and rural communities, seasonal tree shedding generates significant amounts of unmanaged organic waste, often devoid of economic value. A prominent example is the *Butea monosperma* tree, abundantly found across Thailand. Its bright orange-red flowers fall in large quantities during blooming seasons, creating piles of biomass that, while visually striking, remain largely unutilized. The accumulation of these flowers not only demands labour-intensive cleanup but also contributes to environmental clutter. However, this overlooked biomass presents a unique opportunity for sustainable innovation, particularly in low-resource regions with limited access to industrial dyeing inputs and infrastructure [1].

This study builds on earlier work that proposed a value-added approach to this floral waste by extracting natural dye from *Butea monosperma* flowers for cotton fabric dyeing. The prior experiment explored how different dyeing auxiliaries—such as sodium chloride (NaCl), alum (potassium aluminium sulfate dodecahydrate), sodium carbonate (Na<sub>2</sub>CO<sub>3</sub>), and calcium oxide (CaO)—influenced shade development and fastness, without relying on conventional chemical pretreatments [2]. By focusing on simple, locally accessible methods, the process aligned with decentralised and eco-conscious dyeing practices that could support artisanal textile production in tribal areas.

While previous studies have examined *Butea monosperma* as a natural dye source [3,4], there is limited research on optimising dye–fibre interactions using advanced yet sustainable techniques. Notably, electrochemical pretreatment—specifically anodic activation of cotton—has shown promise in improving the affinity between cellulosic fibres and natural dyes by altering fibre surfaces and enhancing dye uptake [5,6]. However, its combined effect with dyeing auxiliaries on shade development and fastness has not yet been systematically explored in *Butea monosperma*.

To expand on the original study's findings, this new set of experiments applies anodic electrochemical pretreatment to cotton fabric before dyeing under identical dye-bath conditions. The aim is to evaluate how this pretreatment step, in conjunction with the previously tested auxiliaries, influences colour strength, shade uniformity, and fastness properties. The electrochemical treatment is conducted under controlled anodic conditions to enhance reactive sites on the fibre surface, thereby promoting stronger interactions with the natural dye molecules.

The core objective of this investigation remains focused on shade development—specifically, how variations in auxiliary type and concentration, when combined with electrochemical pretreatment, affect the depth, vibrancy, and consistency of the resulting dyed shades. These effects are quantitatively assessed using the CIE Lab colourimetric system and standard fastness tests to determine wash and rubbing resistance.

This integrated approach not only strengthens the scientific foundation for natural dyeing with *Butea monosperma* but also offers a potential pathway for improving product quality in heritage textile crafts. The culturally significant role of *Butea monosperma* in Indian traditions [1] further adds value to this work, opening avenues for regional identity reinforcement and potential Geographical Indication (GI) recognition for naturally dyed textiles in Thailand. Ultimately, the research seeks to bridge environmental sustainability, cultural preservation, and economic empowerment in rural communities.