

Natural Mordants in Focus: A Comparative Study of Alum and Calcium Hydroxide in Cotton Dyeing with Senna Siamea Heartwood

Piyanut Jingjit^{a,*}, Yanisa Komonsirichok^b

^a*Rajamangala University of Technology Thanyaburi, Rangsit-Nakorn Nayok Road, Pathum Thani, 12110, Thailand*

^b*Rajamangala University of Technology Lanna, Huay Kaew Road, Muang, Chiang Mai, 50300, Thailand*

Abstract

This study evaluates the dyeing performance of cotton fabric with a natural dye extracted from the heartwood of Senna siamea, focusing on the effects of anodic electrochemical pretreatment combined with varying concentrations of two mordants: potassium aluminium sulfate (alum) and calcium hydroxide. Sodium chloride (10 g/L) was maintained as the auxiliary in all dye baths, while mordant concentrations ranged from 0 to 20 g/L for both alum and calcium hydroxide.

Colourimetric analysis (CIE *Lab**) revealed that alum treatment generally lightened the fabric and decreased colour saturation, with ΔE values reaching 13.11 at 20 g/L, indicating a shift toward washed-out shades. In contrast, calcium hydroxide enhanced fabric brightness and significantly increased yellow chroma, producing warmer and more vibrant hues, particularly at 10 g/L, which was visually the lightest and showed the greatest colour difference ($\Delta E = 14.32$).

Washing fastness (ISO 105-C10) remained consistently good (ratings 3-4/5) across all mordant types and concentrations. Rubbing fastness (ISO 105-X12) improved with increasing mordant concentration, especially for alum at 15-20 g/L and calcium hydroxide at 10 g/L, with wet rubbing ratings improving from 2/3 to 3/4.

These results highlight the distinct influences of alum and calcium hydroxide on colour development and durability, offering practical insights for optimising natural dyeing with Senna siamea extract. The study promotes accessible, eco-friendly dyeing techniques suitable for rural artisans, enhancing traditional textile quality and supporting sustainable production.

Keywords: Senna siamea, natural dye, anodic electrochemical pretreatment, alum mordant, calcium hydroxide mordant, cotton dyeing, sustainable textiles

*Corresponding author.

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

1 Introduction

The resurgence of interest in natural dyes reflects growing concerns over the environmental impact of synthetic colourants and the global push toward more sustainable textile practices. Natural dyes, derived from renewable plant or animal sources, offer a biodegradable and often non-toxic alternative to synthetic dyes, and their use is especially prevalent in rural and artisanal textile production, where they contribute to cultural preservation and local economic development [1, 2]. However, the widespread adoption of natural dyes is hindered by technical challenges, including poor dye-fibre affinity, inconsistent shade reproducibility, and inadequate fastness properties [3].

To overcome these limitations, mordants are employed to facilitate stronger interactions between the dye molecules and textile substrates. Metallic mordants such as aluminium, iron, copper, and tin are commonly used because they form coordination complexes with natural dyes, thereby enhancing colour uptake and improving fastness to washing and rubbing [4]. Among these, potassium aluminium sulfate (alum) is widely favoured for its accessibility and low toxicity. It has been shown to improve colour vibrancy at lower concentrations (5-10 g/L), though it may result in lighter, less saturated hues at higher concentrations (15-20 g/L) [5, 6]. For instance, alum has demonstrated favourable results in dyeing cotton and wool with plant-derived dyes such as annatto, marigold, and walnut bark [7, 8].

In contrast, alkaline mordants such as calcium hydroxide have been less systematically studied in the context of natural dyeing, particularly on cotton fibres. Calcium hydroxide, traditionally used in vat dyeing and batik processes, raises the pH of the dye bath, potentially altering the ionisation states of dye molecules and fibre functional groups, thereby influencing dye fixation behaviour [9]. As a naturally occurring, inexpensive, and widely available compound, calcium hydroxide represents a sustainable alternative for mordanting, especially in rural or resource-limited settings [10]. However, there is a lack of comparative data evaluating its effectiveness compared with more conventional mordants, such as alum, particularly when paired with modern fibre activation techniques.

Recent studies have explored the use of electrochemical pretreatment, particularly anodic oxidation, to modify the surface properties of cotton fibres and enhance dye absorption. This process alters the fibre's surface energy and introduces reactive functional groups, thereby improving dye uptake and uniformity without the need for harsh chemicals [11, 12]. While electrochemical pretreatment has shown promise with synthetic dyes, its synergy with natural dye-mordant systems remains underexplored.

This study aims to bridge this knowledge gap by comparing the dyeing performance of alum and calcium hydroxide mordants on cotton fabric dyed with *Senna siamea* extract following anodic electrochemical pretreatment. By systematically analysing colourimetric properties, shade depth, and fastness characteristics across different mordant concentrations, the research aims to determine how mordant type influences the dye-fibre interaction in this hybrid dyeing system. The findings will contribute to the development of scalable, low-impact dyeing methods for use in artisanal and sustainable textile production.

2 Methods

2.1 Materials

Plain-woven 100% scoured cotton fabric was used as the dye substrate in this study. The natural