

Sustainable Dyeing Techniques: Supercritical CO₂ Cotton Dyeing with Lac Dye with Enhanced Dye Adsorption

Christiana Agbo^{1,2} and Satoko Okubayashi¹

¹ Fiber Science and Engineering, Kyoto Institute of Technology, Matsugasaki, Sakyo-ku, Kyoto 606-8585, Japan
e-mail: okubay@kit.ac.jp

² Department of Fashion Design and Textile Studies, Cape Coast Technical University, Cape Coast, Ghana,
e-mail: christianaagbo907@yahoo.com

Abstract: Supercritical carbon dioxide (scCO₂) was used as a sustainable and ecological means for cotton dyeing using lac dye. Polyethylene glycol 600 (PEG) was used in the pretreatment of cotton which resulted in a considerable increase in colour strength and dye uptake. The colour strength was increased by raising the dye intensity which was evaluated using color strength (K/S) measurements. In addition, Tannic acid (TA) was used as a mordant to improve fastness properties. The dyeing results showed that lac dye had improved K/S values and better fastness on PEG-treated cotton in the presence of TA. The mechanical properties of the dyed samples were also studied. In addition, the system parameters affecting the dyeing properties, including dye concentration, temperature, and dyeing time were examined.

Keywords: Cotton fabrics, Pretreatment, Natural Dyes, Polyethylene glycol, Colour fastness.

Introduction: In recent years, the textile industry has undergone a paradigm shift towards sustainable production methods, driven by the pressing need for eco-friendly alternatives to traditional dyeing processes. Supercritical carbon dioxide (scCO₂) dyeing has emerged as a promising technique due to its low environmental impact, reduced water consumption, and energy efficiency (Beltrame et al., 1998; Fernandez Cid et al., 2005). Cotton on the other hand is extensively used because of its outstanding advantages such as soft handle, comfort, good absorbency, color retention, strength, and breathability. However, with the shift towards sustainable production methods, cotton is faced with a challenge when it comes to dyeing. Approximately 10-15% of dye is lost to the environment through wastewater. Also due to the competitive nature of textile sector production, a surge in the usage of synthetic dye combinations has led to dye wastewater, resulting in an even bigger volume of effluent. However, with growing environmental concerns, the use of an eco-friendly medium such as supercritical carbon dioxide (scCO₂) is being explored. In this study natural lac dye is used, however, despite the numerous benefits, the usage of natural dyes is still restricted due to poor fastness properties. This is because natural dyes mostly have minute or no affinity for cotton mostly due to molecular structures, mostly causing poor fastness (Burwood et al., 1967; Hong et al., 2011; Shamim et al., 2015). As a result, PEG was used as a pretreatment for cotton, acting as a plasticizer to help increase the dyeability of cotton. Also,

the use of mordants such as Tannic acid was employed in forming crosslinks with the cotton fibers and dye, helping to fix the dye molecules as well as enhance the dye-fiber interaction.

Table 1 Color difference and fastness properties of dyed cotton fabrics under scCO₂.

sample	K/S	SD	Washing fastness	Rubbing fastness	
				wet	dry
Lac only	0.85	0.042	4	4	4
PEG/Lac	8.68	0.434	1	2	2
PEG/TA/Lac	11.04	0.121	2-3	3	3

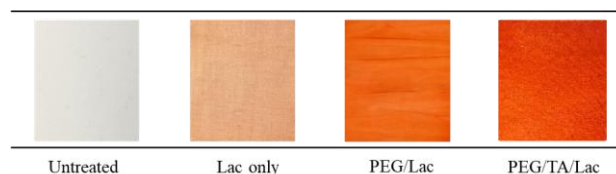


Fig. 1 Influence of pre-treatment/mordant on the apparent color of cotton fabric dyed in scCO₂

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