

Color Strength Variations in Cotton/Jute Blends: Influence of Fiber Composition

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Abstract

This study examines the effect of fiber composition on the color strength of cotton–jute blended textiles. Cotton and jute, both natural fibers with distinct chemical and structural characteristics, were blended in different proportions to evaluate their influence on dye uptake and color strength. The fibers were dyed using reactive dyes through a direct dyeing process then blended and color strength (K/S values) was assessed using spectrophotometric analysis. The findings demonstrated noticeable variations in color strength among the different blend ratios, indicating that fiber composition significantly affects dye absorption behavior. Blends containing higher proportions of jute exhibited increased color strength, attributed to jute’s higher moisture regain and superior water absorbency compared to cotton. The results offer valuable insights for optimizing cotton–jute blends to achieve improved color performance, with practical relevance for textile manufacturers aiming to develop sustainable and high-performance fabrics.

Keywords: Fiber composition; Color strength; Reactive dyeing; Dye uptake; Moisture regain; Sustainable textiles

1. INTRODUCTION

Cellulosic fibers continue to dominate the textile sector because of their comfort, biodegradability, and wide applicability in apparel and technical textiles. Among these, cotton remains the most extensively utilized natural fiber owing to its softness, breathability, and consumer acceptability. However, the growing cost of cotton and the increasing emphasis on sustainability have

encouraged the exploration of alternative natural fibers for blended textile applications (Mittal et al., 1981).

In recent years, environmental concerns associated with textile production, particularly pollution of water and soil resources, have intensified the need for renewable and biodegradable fiber sources. Natural bast fibers such as jute, hemp, sisal, and banana have therefore attracted significant attention as eco-friendly alternatives (Gedik, 2021). Jute is one of the most promising lignocellulosic fibers due to its rapid renewability, low cultivation cost, and minimal dependence on chemical fertilizers. Although its comparatively coarse texture restricts its use in pure form for apparel applications, blending with cotton improves handle, reduces material cost, and enhances certain performance attributes (Shelar & Narendra Kumar, 2021).

One important characteristic influencing dyeing behavior is moisture regain. Jute exhibits a higher moisture regain value than cotton, which promotes better swelling and dye penetration. Consequently, the blend ratio of cotton and jute is expected to influence the final shade depth and color intensity of dyed substrates (Sfiligoj et al., 2013). The color depth of dyed materials is generally expressed through the Kubelka–Munk function (Equation 1):

$$K/S = \frac{(1 - R_{\infty})^2}{2R_{\infty}} \quad (1)$$

where **K** denotes the absorption coefficient, **S** represents the scattering coefficient, and **R[∞]** is the reflectance of an opaque sample. Although several studies have examined natural fiber blends, systematic work on the effect of cotton–jute ratio on color strength remains limited. Therefore, the present study was undertaken to analyze the influence of varying blend composition on dye uptake and shade performance.

2. MATERIALS AND METHODS

2.1 Materials

Cotton fibers used in this study were procured from the Northern India Textile Research Association (NITRA), while jute fibers were sourced from the India Jute Mill, West Bengal. A commercial Dimerene Reactive GB Red dye was selected for dyeing because of its excellent shade brightness and fastness properties. The required auxiliaries and chemicals, including sodium chloride, sodium carbonate, sodium hydroxide, acetic acid, sodium bicarbonate, and soap solution, were obtained from the NITRA laboratory.

2.2 Fiber Characterization

Fiber identification was carried out according to AATCC Test Method 20 using multiple analytical approaches including burning behavior, chemical solubility, microscopic examination, and ATR-FTIR analysis. In the burning test, both fibers exhibited cellulose-like combustion behavior, burning in a paper-like manner without melting or shrinkage. For chemical identification, samples were treated with 70% sulfuric acid, where complete dissolution confirmed their cellulosic nature. Microscopic analysis was performed using a Zeiss projection microscope to observe both longitudinal and cross-sectional morphologies. Further confirmation was obtained through ATR-FTIR spectroscopy using a PerkinElmer UATR TWO instrument over the range of 450–4000 cm^{-1} .

2.3 Dyeing Procedure

Prior to dyeing, the fibers were scoured to eliminate impurities that could interfere with dye penetration. Dyeing was carried out using a 3% shade concentration. The process was initiated at 40 °C for 10 minutes, followed by gradual addition of sodium chloride in three equal portions over 30 minutes. The temperature was then increased to 80 °C. Subsequently, sodium carbonate was introduced in two stages over 40 minutes to facilitate dye fixation. After dyeing, the fibers were thoroughly washed with soap solution, rinsed to remove unfixed dye, and dried under ambient atmospheric conditions.

2.4 Preparation of Blended Samples

The dyed cotton and jute fibers were blended manually in the following weight ratios:

- 80:20
- 60:40
- 50:50
- 40:60
- 20:80

Additionally, 100% cotton and 100% jute were maintained as control samples. The blending process was performed at the NITRA pilot plant to ensure homogeneous fiber distribution.

2.5 Evaluation of Color Strength

Color strength of the blended samples was measured using a Macbeth ColorEye 3100 spectrophotometer connected to a computer color matching system. The values were expressed as K/S, representing shade depth and color intensity.

3. RESULTS AND DISCUSSION

3.1 Fiber Identification

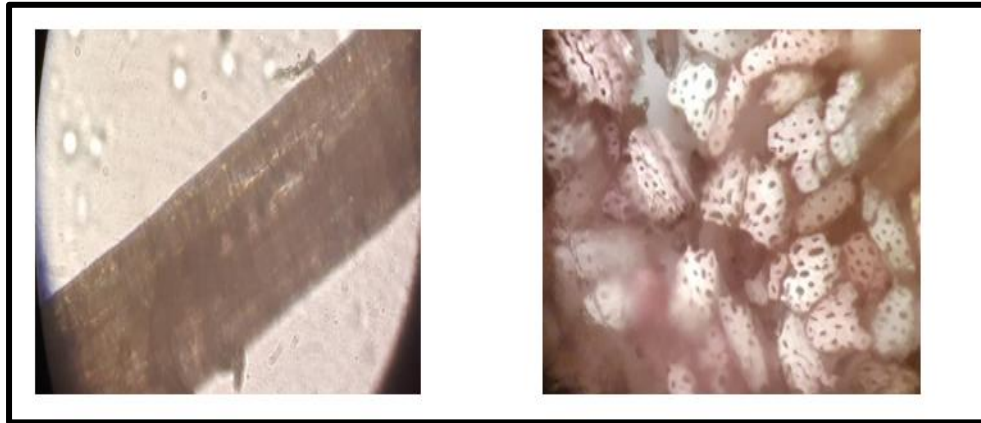
The burning and solubility tests confirmed the cellulosic nature of both fibers. Microscopic observations revealed the typical twisted ribbon-like morphology of cotton along with a kidney-shaped cross section containing a central lumen (Figure:1). In contrast, jute displayed a cylindrical longitudinal appearance with transverse nodes and a polygonal cross section (Figure:2).



(a) Longitudinal view

(b) Cross-sectional view

Figure 1: Cotton Fibers



(a) Longitudinal view

(b) Cross-sectional view

Figure 2: Jute Fibers

FTIR analysis further validated the chemical identity of the fibers. A characteristic absorption peak near 1596 cm^{-1} was observed in jute, indicating the presence of lignin, which was absent in cotton (Fig. 3&4)

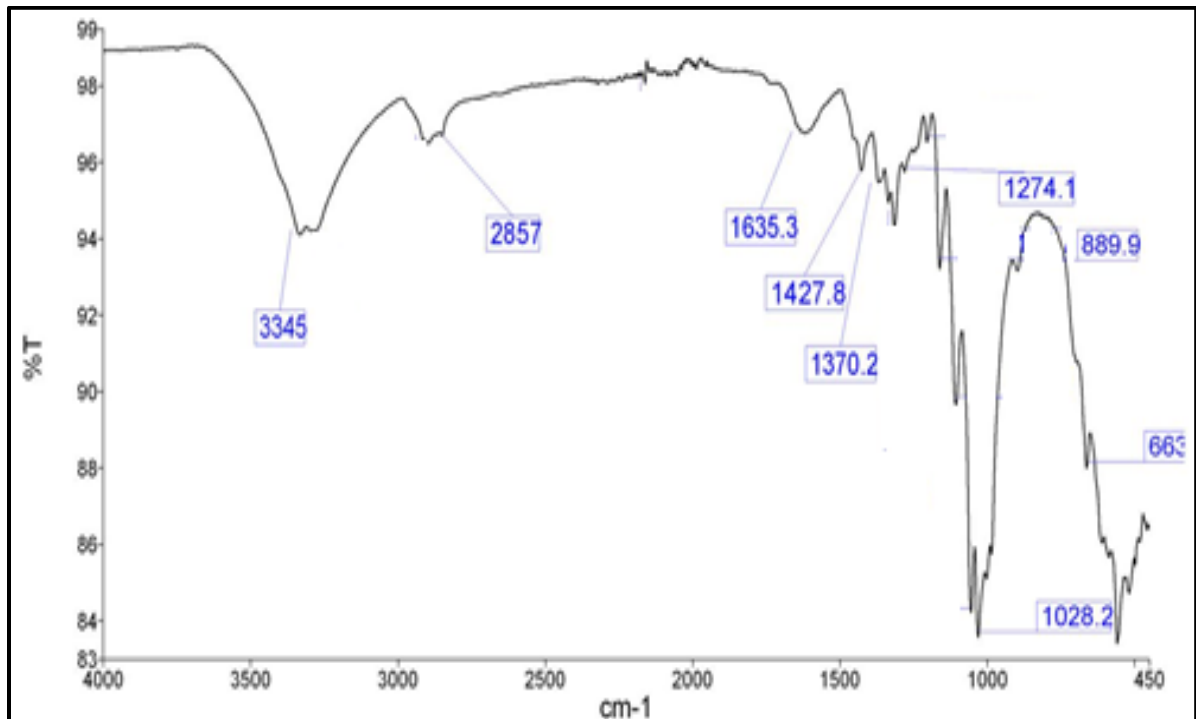


Figure 3: Cotton fiber FTIR

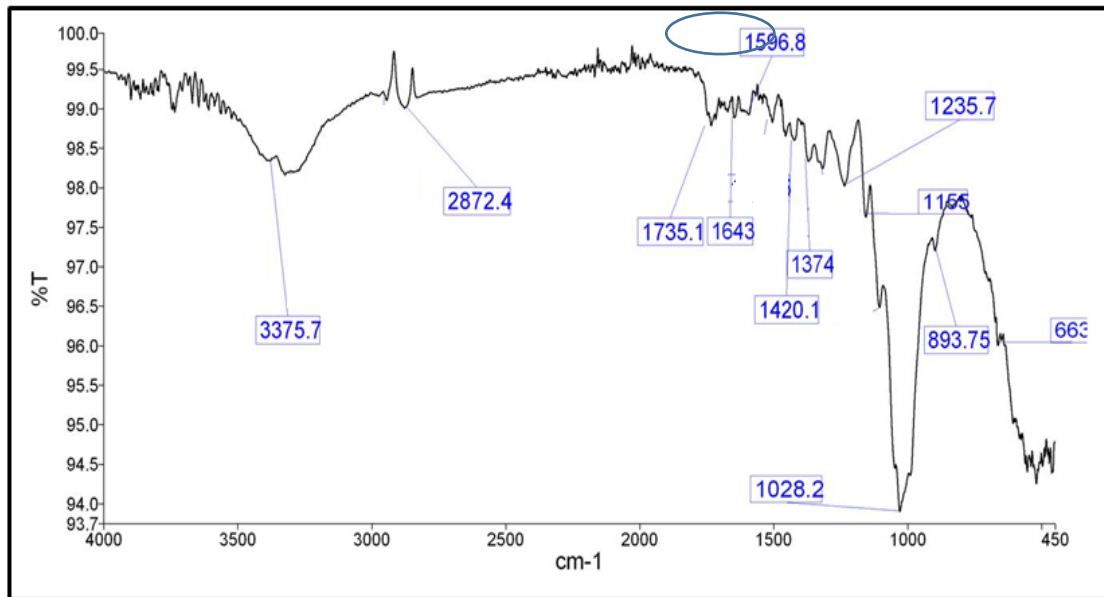


Figure 4: Jute fiber FTIR

3.2 Color Strength Analysis

The K/S values increased consistently with increasing jute content in the blend (Table:2).

Table 2: Cotton/Jute blend Ratio and their K/S value

S.No.	Cotton/Jute Blend Ratio	Color Strength-K/S (Reactive red Dye)
1	100%Cotton	1.81
2	80%Cotton 20%Jute	1.95
3	60%Cotton 40%Jute	2.30
4	50%Cotton 50%Jute	2.42
5	40%Cotton 60%Jute	2.90
6	20%Cotton 80%Jute	3.70
7	100% Jute	5.40

This trend clearly indicates that blend composition significantly influences dye uptake.

The higher moisture regains and swelling capacity of jute fibers likely enhanced diffusion of reactive dye molecules into the fiber matrix, thereby increasing fixation efficiency and final shade depth (Mishra, S., & Behera, B. K., 2016). Blends containing 60–80% jute exhibited notably higher K/S values compared to cotton-rich blends.

3.3 Statistical Analysis

Univariate ANOVA revealed a statistically significant relationship between blend ratio and color strength. Since the obtained p-value was less than 0.05 (table:3), the null hypothesis was rejected, confirming that blend composition has a significant effect on color strength.

4. CONCLUSION

The present study established that the proportion of jute in cotton–jute blends significantly influences dye uptake and resultant color strength.

All characterization techniques confirmed the identity and structural differences of the selected fibers. The experimental and statistical findings consistently demonstrated that increasing jute content leads to higher K/S values due to enhanced moisture absorption and dye fixation. Blends containing 40% or more jute may therefore be considered suitable for applications requiring improved coloration performance along with sustainability benefits.

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