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Effect of Natural Dyes on Jute and Jute-Cotton Blended Fabrics: An Approach of Screen Printing

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Abstract* — *The increasing demand for sustainable and non-toxic textile production has revived interest in natural dyes and biodegradable thickeners as eco-friendly alternatives to synthetic chemicals. This study presents the screen printing on jute-cotton blended fabric using three natural dyes such as turmeric (Curcuma longa), catechu (Acacia catechu), and manjistha (Rubia cordifolia) combined with natural thickener starch. The preliminary results reveal that catechu color performed well based on light fastness (grading 4 out of 5) properties compared to turmeric and manjistha. The rubbing fastness properties were found good in the Manjistha and catechu color applied printed fabric (grading 2-3) compared to turmeric. The GSM study of the catechu printed fabric shows the 35% dye uptake compared to raw jute-cotton blended fabric, 12.7 gm/m^2 was found in the without printed fabric rather than printed fabric it was 19.0 gm/m^2. The bursting strength of the raw jute-cotton blended fabric shows the average time frame 19.1 sec and within the average 400 Kpa pressure which is good enough according to international standard value of bursting strength. The FTIR results were found that the reaction of color with the raw fabric was extreme level. The most intense and complex spectrum was observed for the DP2 means catechu sample (e), indicating the highest level of dye-fiber interaction. This is evident from the significant absorbance in the fingerprint region (900–600 cm^{-1}), where bending vibrations of aromatic and heterocyclic rings in the dye are usually recorded. The use of natural thickener (starch) maintained favorable properties, ensuring smooth screen printability and acceptable print definition.

I. INTRODUCTION

Printing jute-cotton blended fabric with natural dyes and natural thickeners after environmentally friendly chemical processing results in printed jute fabric that may be applied to a range of diverse and high-value applications. Because textiles come into intimate touch with human tissue, they have an immediate impact on people's safety and health (El-Sayed et al., 2021). The textile industry has made significant investments in the development of novel raw materials and printing techniques in response to technological improvements, with the goal of producing high-quality, reasonably priced textiles in large quantities (Kumelachew et al., 2023). However, a number of environmental issues have been brought about by new technology, such as water contamination from the printing and textile processing industries.

These issues have a significant global impact on both climate change and biological ecosystems. People are becoming more conscious of environmental protection, and as a result, they are paying more attention to the pollution that the textile industry causes in the environment (Bhatia & Devraj, 2017). To safeguard the environment and natural resources, governments have developed a number of rules. "The return to a more natural life has been demonstrated in the emergence of organic agriculture and the popularization of natural food," claims a report on the American textile business. Furthermore, it has permeated the textile industry, as seen by the revival of natural dyes and fibers (Reganold & Wachter, 2016).

Natural coloring and dyes have been used for as long as textiles. Textile coloring has always been a human endeavor; the technique dates back thousands of years, and many of the dyes are ancient. It was used in Europe during the Bronze Age (Gupta and V. K. (2020; Pizzicato et al., 2023). Since the introduction of more affordable and generally accessible synthetic dyes with moderate to exceptional fastness capabilities in 1856, the use of natural dyes with poor to moderate fastness has significantly decreased.

However, the use of natural dyes for textile coloring has primarily been limited to small-scale exporters and producers dealing with high-end eco-friendly textile production and sales, as well as craftsmen, small-scale dyers, and printers (Repon et al., 2024; Bechtold T & Mussak 2009; Vankar 2007). In an effort to combat the environmental damage that synthetic dyes do, several commercial dye companies and small-scale export houses are now investigating the possibility of regularly employing natural dyes for textile printing and dyeing (Ahmed et al., 2024). When it comes to coloring, natural colors are much more unique, calming, and delicate than synthetic ones. The number of businesses that are now known to manufacture natural dyes on a commercial scale is modest, but it is growing every day. Adopting suitable and standardized dyeing and printing procedures is necessary for the commercial utilization of natural dyes without compromising the necessary quality of colored textile products. In order to control each treatment, that is, the variables related to the printing and preparation processes, and produce various hues with balanced color fastness, it has also been thought necessary to reexamine and reconstruct the traditional coloration method.

There has been a great deal of work done on natural dye-based textile dying, but relatively little has been done on printing. Rekaby et al. (2009) investigated the use of pigment printing technology to print natural colors from rhubarb and alkanet on natural materials (wool, silk, cotton, and flax). Karolia and Buch [2008] investigated the Ajarkh textiles with resist printing and natural dyes. Reactive cyclodextrin was assessed by Hebeish et al. (2006) for use in cotton printing with henna as a natural color. Hakeim et al. (2005) investigated the pretreatment cotton fabric printed with curcumin, a natural coloring substance, using chitosan. It was discovered that raising the molecular weight of chitosan increased the color yield. In their 2023 study, Hassabo et al. (2023) examined various printing techniques for cotton fabric printing.

Combining jute with cotton fibre could be a viable strategy for diversifying jute and creating value-added products. Jute fibres provide many benefits, including good qualities, a beautiful golden appearance, and great toughness. Therefore, the methods of printing and dyeing could be used to improve the quality of jute and create a new class of jute-based fabrics with a growing market both domestically and abroad. A lot of properties of printed blended jute and cotton fabrics will be assessed in this work. It is assumed that the printing of jute fabric can be tried using natural dyes and suitable printing additives to produce printed fabric with reasonable fastness to washing, rubbing, and light. Therefore, in the present work, blended jute fabric will be subjected to scouring, eco-friendly bleaching, and mordanting, and subsequently printed with natural dyes extracted from indigo, turmeric and catechu and a natural thickener will be utilized for preparing the print paste. Previously, not much research has been associated to find out the Optimization of Eco-Friendly Screen Printing of Jute-Cotton Blended Fabric with Natural Dyes and Thickener Using Central Composite Design**,** besides physical, mechanical, and structural analysis of natural colour printed jute-cotton blended fabric.

II. MATERIALS AND METHODS

Jute cotton blended fabric was prepared following the scouring and bleaching process to take the treatment of mordanting the blended fabric. The scouring and bleaching process make the fabric white soft and lucrative to do screen printing. On this fabric printing colour looks glossy and increases the fabric value.

Jute-cotton blended fabric has been collected from Narayanganj to run this experiment (Fig. 1). This fabric was cut in GSM cutter machine to know its weight in gram per square meter. It was found that 12.7 gm/m^2

Fig.1: Jute-cotton blended fabric

Natural Dyes: Natural color like turmeric, indigo, catechu, and manjistha were selected based on their eco-friendliness and availability shown in Figure 2. This natural color was collected from the Siddik Bazar, old Dhaka. After collecting this color as a raw form, it was blended by using blundering machine to make it powder form. This powder form natural color was used in the printing paste directly to make a colorful printing paste preparation

Fig.2: Turmeric, Catechu, Manjistha and Indigo dye

Thickeners: Natural thickeners like guar gum, xanthan gum, or starch were used as a thickener. In my printing paste the starch gum was used to make printing paste. Figure 3 shows the starch gum and table gum. This gum plays important role to make reaction with the binder and natural dyes to form a required printing paste preparation.

Fig.3: Starch gum

Screen Printing Equipment: The screen-printing frame with different designs were made from Nilkhet printing shop. It was 5 different types of frames and printing book was collected to run the modelling part.

Key Process Parameters:

1. Thickener concentration (%)
2. Screen mesh size (threads per inch)

3. Binder (NK)

4. Fixer

Natural color (3 types: Turmeric, Catechu, Manjistha)

III. EXPERIMENTAL PROCEDURE

Preparation for Printing Paste

Prepare the printing pastes using natural dyes and eco-friendly thickeners according to the Table 1. Ensure homogeneous mixing to achieve consistent paste properties.

Table 1: Printing paste preparation recipe

Chemicals	Amount(gm/liter)
Water	700
Binder	200
Fixer	10
Thickener	15
Softener	10
NK Binder	30
Natural color	35

Screen Printing

Print the jute-cotton blended fabric using the prepared pastes. Maintain consistent printing conditions except for the variables under study. Figure 4 shows the printing frame which has been used for the screen printing

Drying and Curing

Dry and cure the printed fabrics as per the specified conditions in the design matrix.

Evaluation of Printed Fabrics

1) Measure color strength using a crock meter

2) Measuring the GSM after printed sample

3) Light fastness test

4) Evaluate wash fastness according to standard washing protocols.

5) Assess fabric hand feel subjectively and/or through tactile testing methods.

GSM measurement

GSM is an important indicator of fabric compactness, yarn linear density, and end-use suitability. Jute-cotton blended fabrics are widely used in packaging, furnishings, agro-textiles, geotextiles, and eco-friendly apparel. Therefore, accurate measurement of catechu printed fabrics GSM is essential for quality control, product classification, and performance evaluation of jute-based textiles. Equation 1 is followed to measure the GSM of the raw fabric and printed fabric. Figure

$$GSM = \frac{m\ (g)}{A\ (m^2)} \quad g/m^2 \ldots\ldots\ldots\ldots\ldots\ldots \text{(Equation 1)}$$

Fig.4: GSM measurement

Bursting Strength Test

Bursting strength is a key mechanical property of textile fabrics that indicates their resistance to rupture when subjected to multi-directional stress. Unlike tensile strength, which applies force in one direction, bursting strength simulates real service conditions where fabrics experience pressure from all directions simultaneously. Figure 5 shows the bursting strength test applied sample.

Fig.5: Bursting strength test

Color Fastness

Wash Fastness of all the natural printed samples were determined as per ISO standards ISO

105-C05:2010. Wash fastness rating was measured by the computer color matching system

(Spectra scan 5100).

Light Fastness

Light fastness of all the natural printed samples were determined as per ISO standard ISO 105-

B02:2014.

Crock Fastness

Crock fastness (dry and wet) of the printed sample samples were determined as per ISO standard ISO 105-X12:2016.

Whiteness and Brightness:

Whiteness and Brightness (%) of grey and jute-cotton blended fabrics were determined by

Photo voltmeter using green and blue filters. An average of 10 readings were taken for each

fabric samples.

Tensile Properties:

A Testometric Materials Testing Machine was used for evaluation of tensile properties 6 of grey,

and bleached jute fabric samples using the two-inch raveled Strip Test Method (ASTM D5035), i.e., fabric specimen was gripped between two pneumatic jaws of the tensile tester (gauge length

of 20 cm). A continually increasing load was applied longitudinally to the fabric specimen by

moving the upper jaw at an x-head speed of 5 cm/min until the fabric specimen broke. Breaking

load and elongation were determined. Tenacity and extension (%) at break were then

calculated.

Tenacity (cN/tex) $= \frac{(\mathrm{L} \times 100)}{W \times \mathrm{GSM})}$................................ (Equation 2)

L is the breaking load (N), W is the test width (mm), and gsm is the areal density of fabric (g/m^2).

Extension (%) $= \frac{\text{Elongation (mm)}}{\text{Original length (mm)} \times 100}$................................ (Equation 3)

An average of 5 readings, in both warp and weft directions, was taken to represent the tensile

properties of the jute fabric.

Fig.6: Screen printing frame

IV. RESULTS AND DISCUSSIONS

Study on Catechu Color Printing

Three different weight percentages of catechu, turmeric, manjistha color was measured in the Sartorius balance with a scale of 20 gm, 40gm and 60 gm. The coloring powder was mixed with the printing paste to the designated paste preparation recipe and paste was finally applied on the jute-cotton blended fabric.

Study on GSM

GSM (Grams per Square Meter) is a critical physical property used to express the mass or weight of a fabric. In jute fabrics, GSM reflects the bulk, strength, and durability, which are essential for industrial, packaging, and fashion applications (e.g., bags, home décor, blended textiles). In this study, before printing the jute-cotton blended fabric the gram per square meter of the fabric was measured (12.7 & 12.3 gm/m^2). After printing with catechu color, the GSM increased 35% of the fabric (19.0 & 19.7 gm/m^2) (Fig.6).

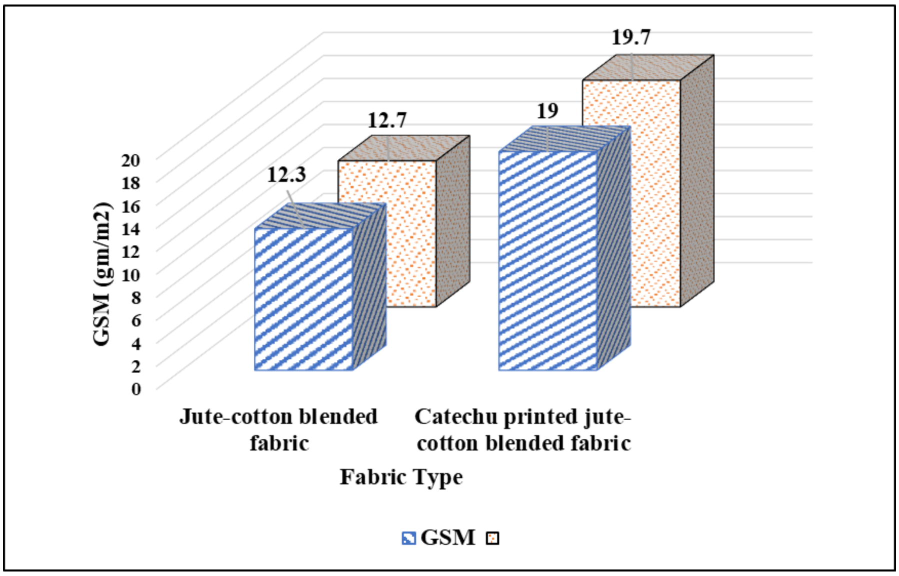

Fig.6: GSM measurement

Study on Bursting Strength Test

Bursting strength refers to the ability of a fabric to withstand pressure applied perpendicular to its surface until rupture. It is particularly important for fabrics used in applications that experience multi-directional stress, such as sacks, bags, and upholstery. In the context of jute fabric, bursting strength is a key mechanical property, given jute's coarse texture and use in load-bearing textiles.. It reveals that the catechu printed sample shows the highest bursting strength test results (428.6 Kpa) within 20.6 seconds. Figure 7 shows the bursting strength test results on 2 types of fabric.

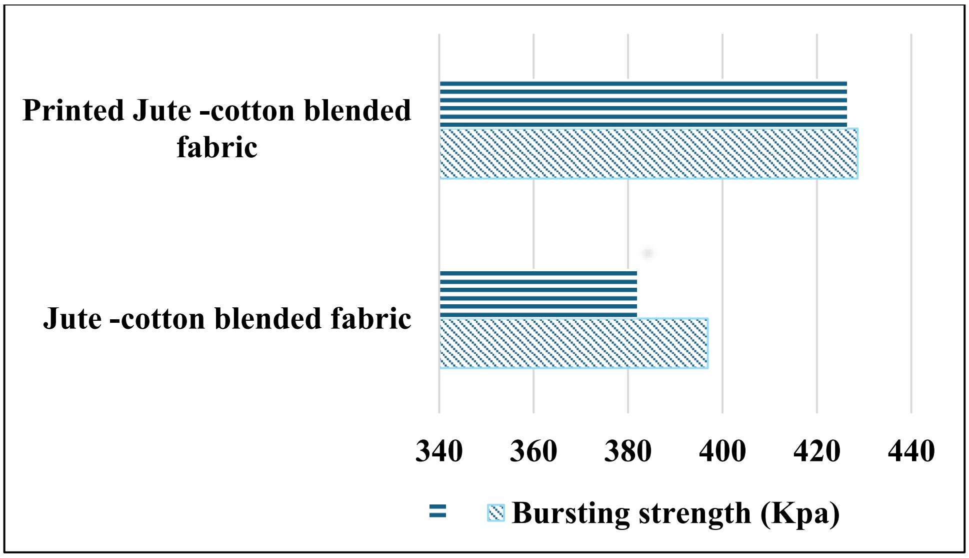

Fig.7: Bursting strength test

Study of Wash Fastness

Wash fastness refers to the resistance of dyed or printed fabrics to washing or laundering. It is an essential quality parameter, especially for jute-cotton blended fabrics printed with natural dyes, as these fabrics are expected to retain color after repeated washes in sustainable textile applications. Table 2 shows the wash fastness on catechu printed blended fabric. It shows that the natural color printed fabric rated 2-3 wash fastness which is internationally acceptable because of natural color application.

Table 2: Wash Fastness on different color percentage of catechu printed blended fabric

No.	Wash Fastness on Catechu printed fabric		
	Loss of depth of shade	Staining	Cross Staining
01.	2	3	3
02.	2	3	3
03	2	4	3
04	2-3	3	3

Study of Color Fastness

Color fastness is a key performance criterion in evaluating the durability and applicability of dyed textiles. In this study, the jute-cotton blended fabrics were printed using three natural dyes are Catechu, Turmeric, and Manjistha were tested for their light fastness and crocking (rubbing) fastness properties. The results are summarized in Table 4.3.

Light Fastness

Light fastness refers to the resistance of printed or dyed fabric colors to fading or degradation upon exposure to sunlight or artificial light (UV radiation). For jute-cotton blended fabric printed with natural dyes, light fastness is a crucial parameter, especially for home textiles, fashion, or outdoor applications where exposure to light is common. In this study 3 different color Turmeric, Catechu and Manjistha was used to observe the light fastness properties. The results demonstrate that Catechu-dyed samples exhibit relatively good light fastness ratings of 4, showing strong resistance to photo-degradation. Manjistha-dyed samples exhibited moderate light fastness values ranging between 3 and 4, while Turmeric-dyed fabrics performed the worst, with values between 2 and 3, reflecting poor resistance to fading under light exposure.

Rubbing Fastness

Rubbing fastness (also called crocking fastness) refers to the resistance of dyed or printed fabric to color transfer when rubbed against another surface. This is especially significant for jute-cotton blended fabrics printed with natural dyes such as turmeric, catechu, and manjistha, which often exhibit variable rubbing resistance due to their poor fixation on cellulose fibers. Dry crocking fastness values were consistently high across most samples, ranging from 4 to 4–5, indicating very good resistance to dry rubbing. Wet crocking, however, showed significantly lower fastness. Catechu and Turmeric samples generally recorded values of 1–2, indicating a tendency for color bleeding when wet. In comparison, Manjistha showed slightly better wet fastness, scoring 2–3, which suggests moderate resistance. These results highlight the limitations of certain natural dyes, particularly in moisture-exposed conditions, despite their ecological benefits.

As shown in Table 3, the natural dye Catechu exhibited the best overall performance, particularly in light and dry crock fastness, although its wet fastness remains low. Manjistha provides a balanced performance with moderate ratings in all categories. In contrast, Turmeric, despite its vibrant color, shows poor light and wet rubbing fastness, limiting its applicability without further treatment or mordanting.

Table 3: Light Fastness and rubbing fastness on different color (turmeric, catechu & manjistha) printed blended fabric

No.	Fastness properties		
	Light fastness	Crock Fastness	
		Dry	Wet
01.	4 (catechu)	4	1-2
02.	4 (catechu)	4-5	2
03	4 (catechu)	4-5	1-2
04	4 (catechu)	4	1-2
05	2-3 (turmeric)	4	1-2
06	2 (turmeric)	4-5	1-2
07	3-4 (manjistha)	4-5	2-3

Fourier Transform Infrared (FTIR) Spectroscopic Analysis

FTIR spectroscopy was employed to investigate the chemical interactions and structural modifications of the jute-cotton blended fabrics before and after dyeing with Indigo DP at different dyeing penetration levels (DP2 catechu, DP32 turmeric, DP40 manjistha). The FTIR spectra of the raw and dyed fabrics are shown in Figure 8, with spectral bands ranging from 4000 to 500 cm^{-1}.

Raw Fabric (a)

The spectrum of the untreated (raw) fabric exhibits characteristic absorption bands associated with cellulose, the main component of jute and cotton fibers. A broad peak observed around 3300 cm⁻¹ corresponds to O–H stretching vibrations, indicative of hydroxyl groups in cellulose. The C–H stretching bands at approximately 2900 cm⁻¹ also confirm the presence of alkyl groups in the cellulose structure. Additionally, peaks observed in the region of 1000–1200 cm⁻¹ are attributed to C–O–C and C–C stretching vibrations, which are typical of polysaccharide backbones.

Dyed Fabrics – Indigo DP and DP Treatments (b to e)

Noticeable changes in the FTIR spectra of the dyed fabrics (b to e) confirm the successful interaction of the natural dye with the fabric structure. The spectrum labelled as (b), representing the Indigo DP treated sample, exhibits new peaks or increased intensity in regions associated with carbonyl (C=O) and aromatic (C=C) groups, particularly around 1650–1600 cm⁻¹. These peaks are attributed to the aromatic structures and conjugated systems present in the Indigo dye molecules.

As the dye penetration level increases from DP40 (c) represents Manjistha to DP2 (e) represents Catechu, the intensity of the characteristic peaks becomes more pronounced. The broadening and shifting of the O–H stretching band near 3300 cm⁻¹ in the dyed samples suggest potential hydrogen bonding between the hydroxyl groups of cellulose and the functional groups of the dye. Additionally, enhanced peaks around 1000–1300 cm⁻¹ reflect the presence of C–N and C–O stretching, likely resulting from the interaction of dye molecules with the fibre matrix.

The most intense and complex spectrum was observed for the DP2 means catechu sample (e), indicating the highest level of dye-fibre interaction. This is evident from the significant absorbance in the fingerprint region (900–600 cm⁻¹), where bending vibrations of aromatic and heterocyclic rings in the dye are usually recorded.

The progressive increase in band intensity and the emergence of new peaks in the dyed fabrics compared to the raw fabric confirm the successful deposition and chemical bonding of the Indigo DP dye onto the jute-cotton substrate. The FTIR results support the effectiveness of the dyeing process and the strong interaction between the dye and the fibre, especially at higher dye penetration levels such as DP2 (catechu).

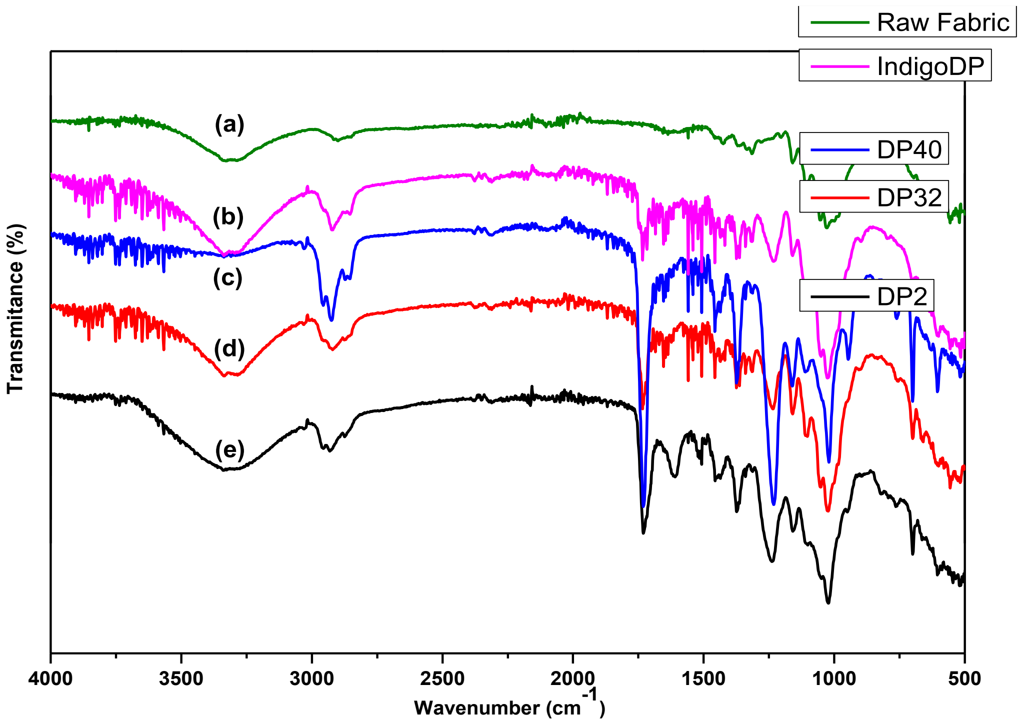

Fig.8: FTIR analysis on Turmeric, Catechu, Manjistha, Indigo color printed fabric with jute-cotton blended fabric

V. CONCLUSION

The preliminary experiment result shows that the rubbing fastness properties was found good in the Manjistha and catechu color applied printed fabric (grading 2-3) compared to turmeric. The GSM study of the catechu printed fabric shows the 35% dye uptake compared to raw jute-cotton blended fabric, 127 gm/m² was found in the without printed fabric rather on printed fabric it was 190 gm/m². The bursting strength of the raw jute-cotton blended fabric shows the average time frame 19.1 sec and within the average 400 Kpa pressure which is good enough according to international standard value of bursting strength. The FTIR results were found that the reaction of color with the raw fabric was extreme level. The most intense and complex spectrum was observed for the DP_2 means catechu sample (e), indicating the highest level of dye-fiber interaction. This is evident from the significant absorbance in the fingerprint region (900–600 cm^{-1}), where bending vibrations of aromatic and heterocyclic rings in the dye are usually recorded. The use of natural thickener (starch) maintained favorable properties, ensuring smooth screen printability and acceptable print definition.

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AUTHOR CONTRIBUTION

Mir Akmam Noor Rashid served as the Project Investigator (PI) and conducted experiments, characterization, data collection, and analysis. He also played the main role in writing the manuscript and developing research ideas. Shuranjan Sarkar and MM Alamgir Sayeed provided technical assistance in achieving the research outcomes. Ayesha Khatton, as Co-PI, and Moslem Uddin helped to manage official documentation and provided logistical support.

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DECLARATION

Not applicable, as this study did not involve human participants or animals.

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