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Comparison of dyeing performance between jute-cotton blended fabric and cotton fabric, using reactive dyes

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Abstract

The global trend is shifting back towards natural fibres, with jute-cotton blended fabric being a prime example of a sustainable product made from two natural fibres. Ensuring an efficient and effective dyeing process is essential for the long-term use of jute-cotton blended fabric. This research project focused on investigating the dyeing process of jute-cotton blended fabric in a single step and evaluating the wash and rubbing fastness of the dyed fabric. To evaluate the dyeing results, jute-cotton blended fabric and cotton fabric were produced using the same equipment and subjected to identical dyeing methods. The reflectance curve and DEcmc value were then analyzed. The reflectance curve displayed a consistent pattern, with a DEcmc value below 1. Rubbing fastness measures the fabric's ability to resist colour change and staining when rubbed. The overall results indicated good resistance, measured on a grey scale from 4 to 5. Wash fastness, on the other hand, assesses the fabric's ability to resist colour change and staining during washing. The staining grey scale result was 3, while the colour change grey scale was 4. The jute-cotton blended fabric sample had 48 Ends per inch (EPI), 36 Picks per inch (PPI), and a weight of 221 grams per square meter (GSM).

Keywords: Jute-cotton blended fabric; Reactive dye; Fastness.

1. Introduction

The utilization of natural fibers is gaining momentum once again, with the world returning to their use. One such example is the jute-cotton blended fabric, which combines two natural fibers to create a unique product. In order to ensure the sustainable utilization of this fabric, it is essential to have an effortless and appropriate dying procedure [1]. Jute fiber is known for its strength, durability, and versatility, making it a popular choice for various applications such as textiles, packaging, and construction materials [2, 3]. The presence of lignin in jute fiber gives it a natural resistance to microbial degradation and makes it suitable for use in humid and moist environments [4]. Additionally, the high cellulose content in jute fiber gives it excellent tensile strength and makes it an ideal material for producing strong and durable products. The unique composition of jute fiber also makes it biodegradable and environmentally friendly, as it can easily decompose without causing harm to the environment. This makes jute fiber a sustainable alternative to synthetic fibers that are non-biodegradable and contribute to environmental pollution. Overall, the chemical composition of jute fiber sets it apart from other natural fibers and gives it a distinct set of properties that make it a valuable and versatile material for a wide range of applications. Jute fiber is chemically distinct from cellulosic fibers like cotton due to its composition of lignin and cellulose. Its primary components include cellulose (54-60%), hemicellulose (20-24%), and lignin (12–14%). The fiber consists of the -OH group of cellulose, the secondary -OH group of hemicellulose, the gluco-uronic acid residue of hemicellulose's -COOH group, and a minor quantity of unsaturated lignin [5-8]. The composition of Jute, a natural fiber, consists of multiple constituents and additional functional groups [9]. Consequently, the kinetics of dyeing jute with different synthetic dyes may or may not resemble that of cotton.

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Cotton, primarily composed of cellulose, undergoes reactions with moisture, dyes, finishing chemicals, and chlorine bleach. Hence, from a chemical standpoint, cotton can be classified as a cellulosic fiber [10]. Direct dyes, reactive dyes, vat dyes, and sulfur dyes are all viable options for coloring cotton fibers. Among these, reactive dyes are particularly popular for dyeing cotton fibers due to their anionic reactive groups [11]. What sets reactive dyes apart from other dyes is their ability to form covalent interactions, specifically in alkaline conditions, between the carbon atoms of the dye reactive group and the oxygen atoms of the hydroxyl groups present in cotton [12,13]. It is worth noting that jute cellulose also contains hydroxyl groups with oxygen atoms, further emphasizing the unique nature of reactive dyes. Reactive dyes necessitate a significant quantity of salt to mitigate the electrostatic repulsion that arises between cellulose fibers and anionic dyes [11]. This is due to the fact that cellulosic fibers, such as jute and cotton, possess negative charges. The utilization of reactive dyes in the dyeing process of jute is widely favored due to their reasonable cost, extensive range of colors, and superior colorfastness [14]. Nevertheless, there are environmental concerns associated with reactive dyes. One such issue is their excessive salt requirement, which can result in the production of hydrolyzed dyes that exhibit poor wash fastness [15]. Researchers have devised reactive dyes containing various reactive groups and dyeing methods to address these issues. Reactive dyes are considered more suitable for industrial purposes on jute fibers due to their superior color fastness and lower exhaustion compared to basic dyes [16]. Basic dyes also exhibit good color fastness when subjected to temperature and shade variations, as well as washing, rubbing, and light exposure [17]. In contrast, reactive dyes yield exceptional outcomes in terms of dye fixing rate, dye fastness (washing, rubbing, light, and perspiration), and tensile strength of cross-linked colored jute fabrics. Blended fabrics are manufactured to leverage the benefits of constituent fibers, with various types of blended fabrics available [18]. Different methods are employed for dyeing blended fabrics. In the conventional exhaust dyeing method for P/C (polyester/cotton) blends, each component is dyed separately under optimal conditions using a two-bath process. To address productivity issues and address increasing environmental concerns, numerous initiatives have been made in the past to streamline this process into single-bath procedures [19]. Novacron reactive dyes are known for their larger molecular size, making them particularly suitable for dyeing jute and jute-cotton union fabrics [20]. In the case of jute-cotton union fabric, cotton yarn is typically used as the warp while jute yarn serves as the weft yarn. One potential solution to reduce the reliance on cotton is by blending jute with cotton, offering a more diverse and sustainable approach to textile production [21]. The coloring of jute-cotton blend fabrics poses a challenge for researchers due to the greater crystalline structure and lack of cellulose structure in jute fibers compared to cotton [22]. However, blending cotton with jute can enhance properties such as drape, comfort, durability, and dye absorption. The production of jute-cotton blended yarn and fabric is feasible, allowing for a wide range of applications [23]. Therefore, applying color to these blends is essential to meet various needs. Jute and cotton, being both cellulosic fibers, can be combined at the initial stage and dyed individually using reactive dyes. The main objective of this research is to examine the dyeing procedure of jute-cotton blended textile in a one-step process, as well as to assess the fabric's wash and rubbing resistance. The focus is on analyzing jute-cotton blended fabric made from jute-cotton blended yarn and colored with reactive dye in a single process. The results are anticipated to provide a pragmatic understanding of the fundamental color properties of the dyed textile, aiding individuals in their decision-making.

2. Materials and method

2.1. Materials

Jute-cotton blended fabric using jute-cotton blended (50:50) yarn was produced in the Jute-Textile Wing of Bangladesh Jute Research Institute (BJRI) which was used as the sample for this work. Cotton fabric was also produced for this work. Jute and Cotton fiber have been collected from the local market.

2.2. Methods

2.2.1. Production of cotton yarn and fabric

For the production of cotton yarn at first, the collected raw cotton fiber was fed in the Blowroom. Then the produced lap was fed into the Carding machine following the Drawing machine. From the drawn sliver a hundred percent cotton yarn was produced. Warp yarn was collected from the local market and produced cotton yarn has been used in the weft direction for manufacturing cotton fabric.

2.2.2. Production of jute-cotton blended yarn and fabric

Raw jute fiber is longer than cotton fiber. For the production of jute-cotton blended yarn at first, the collected raw jute fiber was cut into short fiber. Then this fiber was chemically treated and dried. After that cotton and treated jute fiber were mixed in the Blow room at a 50:50 ratio in weight. The produced lap was then fed into the Carding machine following the Drawing machine. From the drawn sliver jute-cotton (50:50) blended yarn was produced. Cotton yarn has been used in the warp beam and jute-cotton (50:50) blended yarn has been inserted in the weft direction for producing jute-cotton blended fabric. This sample fabric will be named as jute-cotton blended fabric in this document.

2.2.3. Selection of fabric structure

The weave structure of a fabric is very basic and important information while working with a fabric. There are different types of fabric structures available. Among them, plain fabric is the most common structure and can be easily produced in all types of looms. One up one down simple plain fabric has been produced in the rapier loom of the product development division for this study.

2.2.4. Determination of EPI and PPI

Ends per inch (EPI) and picks per inch (PPI) were determined by using a magnifying glass and counting the number of threads per inch in both warp and weft directions. It was also done by cutting the fabric in one inch in warp and weft direction. Then the number of warp threads and the number of weft threads were counted. EPI and PPI have been measured of the grey fabric.

a. Counting glass b. Warp yarn c. Weft yarn

Figure 1 a. Depicts the method of EPI and PPI measurement using a magnifying glass. Figure 1 b. and 1c. shows the threads of wrap and weft yarn after removing from the fabric.

2.3. Determination of GSM

Weight in grams per square meter of the fabric samples has been measured by using a GSM cutter and electric balance. At first, the sample fabric was cut with the help of a GSM cutter. Then the cut sample was measured and the gram per square meter was calculated. The GSM of the grey fabric has been measured. In Figure 2 a., the process of fabric cutting using a GSM cutter has been shown, and in Figure 2 b. shows the cut grey fabric sample which was weighted in the electric balance.

a. GSM cutter b. Sample for GSM measurement

Figure 2 a. The process of fabric cutting using a GSM cutter has been shown, and in Figure 2 b. shows the cut grey fabric sample which was weighted in the electric balance.

2.4. Pretreatment of sample fabric for dyeing

The grey fabric produced in the Rapier Loom cannot be used directly in the dyeing process. It contains various types of dirt and impurities. Pretreatment is the preparation process for grey fabric for subsequent processes of coloration and finishing. It is a series of cleaning operations for removing the impurities that can cause adverse effects in dyeing, printing, and finishing. The very first pretreatment step is the Singeing of the fabric. It is done to remove the protruding fibers from the fabric surface. This process is mainly done by the gas singeing process. This step was unable to be carried out due to the unavailability of the arrangements.

2.5. Desizing

Desizing is one of the initial wet treatments on grey fabric for removing size materials from the fabric. Size material is normally applied to warp yarns before the weaving process. The applied size gives the warp yarn sufficient strength and flexibility required to withstand the weaving operation forces acting on the warp yarn. Although sizing is good for the weaver to run smooth production, it is a problem for the wet processing steps as the sized fabric has lower wettability. And low wettability makes dyeing and finishing processes difficult and non-uniform. There are different techniques of desizing available namely hydrolytic desizing, Bacterial desizing, enzymatic desizing, acid steeping, Oxidizing desizing etc. The fabric sample was impregnated with 2.5 g/l acid solution at room temperature for eight hours and then washed thoroughly. The same procedure has been followed for the hundred percent cotton fabric.

2.6. Scouring and bleaching

Cotton and jute both are natural fibers and contain impurities. Natural impurities such as mineral matter, oils, waxes, and ashes hinder the penetration of dyes and chemicals into the interior of fibers. As a result, dye wastage and uneven dyeing faults occur. To remove these impurities the cellulosic fibers are treated with alkali and auxiliaries at high temperatures which is known as the scouring process. Due to this treatment impurities including oil and wax are removed and the fabric becomes more absorbent. Bleaching is the process of removing natural colors from the fibers to achieve the whiteness for development of true color. There are different types of bleaching processes available. In this study, one-step scouring and bleaching have been done. The jute cotton blended sample fabric was treated with 3 g/l caustic soda, 3 g/l hydrogen peroxide, 0.5 g/l wetting agent, 1g/l detergent, and 0.5 g/l stabilizer at 90-95 ^{o}C for 50 minutes. Then the sample was rinsed and neutralized. This sample is then dyed with reactive dye in a sample dyeing machine. The same procedure has been followed for the hundred percent cotton fabrics.

2.7. Dyeing of sample fabric

The pretreated jute cotton blended fabric was dyed with a medium shade of 2% owf (On the weight of the fabric) reactive dye in a sample dyeing machine. The jute cotton blended sample fabric has been dyed with 2% reactive dye, 60 g/l common salt, 20 g/l soda ash, and 1 g/l wetting agent at 60 ^{o}C for 60 minutes. After dyeing the sample fabric was thoroughly rinsed and followed by an acid wash for neutralization. Finally, a good wash was given and then dried in the environmental open air. The prepared dye solution and sample dyed fabric are shown in Figure 3. (a, b, and c).

a) Dye solution **b) Sample fabric immersed in the solution** **c) Dyed sample**

Figure 3. a) Depicted the preparation of dye solution. Figure 3. b) shows the sample fabric immersed in the solution and Figure 3. c) shows dyed fabric sample

Figure 4 The machine in open and close state.

The procedure has been carried out using ECO DYER machine. Figure 4 shows the machine in open and close state. The same procedure has been repeated for the hundred percent cotton fabric.

2.8. Test Methods

2.8.1. Handle and visual assessment

For any kind of colored fabric, the very first assessment is the hand feel and visual appearance which is done manually.

2.8.2. Spectrophotometer

A spectrophotometer is an instrument that accurately quantifies electromagnetic radiation at particular wavelengths of light. It employs the properties of light and energy to visualize colors and quantify the amount of each colour in a light beam. A spectrophotometer of X-rite Company has been used for this study. The dyed cotton fabric has been selected as the standard sample and the dyed jute-cotton blended fabric has been tested against the dyed cotton fabric. The process has been depicted in Figure 5 below.

Figure 5 Depicted the sample test process in spectrophotometer

2.9. Colour fastness

Colour fastness refers to the durability of colour in a dyed or printed textile material against fading or bleeding caused by many factors such as water, light, rubbing, washing, perspiration, and other common exposures in textile production and everyday use [24]. Colour fastness is typically evaluated by considering two independent factors: 1. The extent to which the colour of the tested specimen changes, known as colour fading. 2. The degree to which the colour of the specimen transfers onto undyed material in touch with it during the test, known as staining of colour. Rubbing and Wash fastness is represented by a 1 to 5 scale where 5 represents very good fastness and 1 represents poor fastness. The grey scale used for the grading is shown in Figure 6.

Figure 6 The grey scale used for the grading

The grading of color fastness for wash and rubbing is given below in the Table 1.

Table 1 The Grade for Rubbing and Wash fastness

Grade	Fastness Type
1	Poor
2	Moderate
3	Good
4	Very Good
5	Excellent

2.10. Rubbing fastness procedure

Crocking fastness or rubbing fastness has been done by using a Prowhite rubbing fastness tester situated in the Testing laboratory of Jute-Textile Wing, BJRI. The dyed fabric sample has been rubbed by the rubbing head with crocking cloth both for dry and wet rubbing procedures. AATCC TM 08 has been followed for the rubbing fastness test. The rubbing fastness test procedure is shown in Figure 7.

Figure 7 The rubbing fastness test procedure

2.11. Wash fastness procedure

The jute cotton blended dyed sample fabric has been washed with 5g/l of soap and 2g/l of soda ash in a solution of liquor ratio 50:1, at a temperature of 60˚C for 30mins along with a piece of multifiber, followed by rinsing and drying. The dried sample of washed dyed sample and multifiber are shown in Figure 8 below.


Figure 8 The jute cotton blended dyed sample (left) and multifiber (right) after washing

3. Results and Discussion

3.1. Fabric specification

The greyjute-cotton blended fabric produced from jute-cotton blended (50:50) yarn has EPI 48 of PPI 36 and GSM 221. This fabric has One up one down simple plain-woven structure.

3.2. Appearance and hand feel of the dyed sample

Visually the dyed jute-cotton blended fabric produced from jute-cotton blended (50:50) yarn looks good, even, and no harsh hand feel was observed. However, a very minor whitish effect can be noticed in comparison to the hundred percent cotton fabric which may be the result of jute fiber contained in the blended sample.

3.3. Spectrophotometer

Table 2 The result of the spectrophotometer

Standard Name	**ill-obs**	**L***	**a***	**b***	**C***	**h**
Sample 1 cotton	D 65-10	40.24	55.59	-2.69	55.65	357.23
	A -10	47.25	54.02	11.36	55.20	11.88
	F02-10 (CWF)	39.03	42.24	-6.11	42.68	351.78

Standard Name	ill-obs	DL*	Da*	Db*	DC*	DH*	DEcmc	P/F DEcmc	MI-(1,2)
Sample 2 Jute/Cotton	D65-10	-1.43 D	0.48 R	2.46 Y	0.41 B	2.48 Y	1.52	Failed	0.43
	A -10	-1.20 D	0.51 R	2.83 Y	1.14 B	2.64 Y	1.71		
	F02-10	-1.46 D	0.37 R	2.34 Y	0.10 B	2.37 Y	1.58		
sample 3 jute cotton	D65-10	0.34 L	-0.10G	0.86 Y	-0.13D	0.85 Y	0.49	Passed	0.10
	A -10	0.36 L	-0.19G	0.89 Y	0.00	0.91 Y	0.56		

	F02-10C	0.51 L	0.01	1.07 Y	-0.13D	1.06 Y	0.68		
sample 4 jute cotton	D65-10	-0.16 D	-0.38G	0.98 Y	-0.41D	0.96 Y	0.54	Passed	0.07
	A -10	-0.16 D	-0.44G	0.96 Y	-0.22D	1.03 Y	0.62		
	F02-10C	0.00	-0.23G	1.18 Y	-0.38D	1.14 Y	0.68		

The cotton fabric dyed with 2 % reactive dye is depicted as sample 1 cotton and inserted as standard sample in the spectrophotometer. Three different illuminants have been considered namely D65 (noon sky daylight), A (tungsten), and F02-10 (CWF)(fluorescent). Three test specimen of jute-cotton blended dyed fabric have been compared against the standard cotton fabric. Among the three samples, one sample has average higher DEcmc than one and failed the test. Other two samples have a lower DEcmc value than 1 and passed the test.

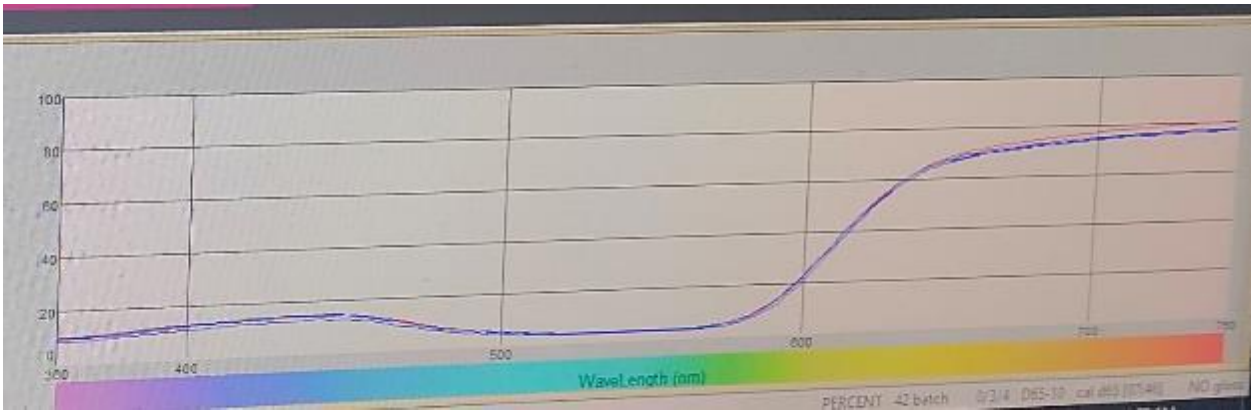

Figure 9 Reflectance curve of cotton and jute-cotton blended dyed fabric

The reflectance curve of the tested sample has been depicted in Figure 9. The graph shows the reflectance curve in the spectrum wavelength range from 360 to 750 nm. All the samples show similar trend and nearly overlap one other. Jute-cotton blended fabric and cotton fabric both have cellulose and it creates covalent bond with reactive dye. Therefore, all the samples have shown the same trend.

Table 3 Rubbing fastness of dyed cotton fabric

Sl. No.	Dry rubbing		Wet Rubbing	
	Staining on white cotton	Color change	Staining on white cotton	Color change
1	5	5	4-5	4-5
2	4-5	4-5	4-5	4-5
3	5	5	4-5	4-5
4	4-5	4-5	4-5	4-5
5	5	5	4-5	4-5

Table 4 Rubbing fastness of jute-cotton blended dyed sample fabric

Sl. No.	Dry rubbing		Wet Rubbing	
	Staining on white cotton	Color change	Staining on white cotton	Color change
1	4-5	4-5	4-5	4-5
2	4-5	4-5	4	4

3	5	5	4	4
4	4-5	4-5	4	4
5	5	5	4	4

Table 3 and Table 4 represent the rubbing fastness properties of cotton fabric and jute-cotton blended fabric dyed with reactive dye respectively. Five tests have been done. Dry rubbing properties of cotton fabric lies between 4-5 and five for both color change and staining grey scale. Wet rubbing properties results 4-5 for both color change and staining grey scale. Therefore, cotton fabric shows good to very good rubbing fastness in this experiment. On the other hand, jute-cotton blended fabric results 4-5 to 5 dry rubbing fastness in both staining and color change grey scale. Jute-cotton blended sample has an average result 4 in both the staining and color change grey scale, which is lower than the cotton sample fabric. Due to the presence of jute fiber in the jute-cotton blended fabric sample, the wet rubbing is slightly lower than that of cotton fabric sample.

3.4. Wash fastness results

Table 5 Wash fastness of dyed cotton fabric

Sample No	Staining in						Color change
	Acetate	Cotton	Polyamide	Polyester	Acrylic	Wool	
1	5	4	4-5	5	5	5	4-5
2	5	4-5	5	5	5	5	4-5
3	5	4-5	5	5	5	5	4-5

The Wash fastness properties of cotton fabric and jute-cotton blended fabric dyed with reactive dye have been listed in Table 5 and Table 6 respectively. Three tests have been done for wash fastness measurement. Cotton fabric sample shows 4-5 (good to very good) results in the case of staining and in colour change scale the difference is very slight resulting a grading of 4-5. In colour change grey scale, jute-cotton blended sample shows results between 4 and 4-5 which is very close to the result of cotton sample. However, in the staining grey scale jute-cotton blended fabric shows results between 3 to 3-4 which is one grade lower than the results of cotton sample. Jute fiber contains a lower percentage of cellulose than cotton fiber which may result in lower wash fastness properties.

Table 6 Wash fastness of jute-cotton blended dyed sample fabric

Sample No	Staining in						Color change
	Acetate	Cotton	Polyamide	Polyester	Acrylic	Wool	
1	5	3	4	5	5	5	4
2	5	3-4	4-5	5	5	5	4-5
3	5	3	4	5	5	5	4

4. Conclusion

The jute-cotton blended fabric, which is a combination of natural fibers, has been found to yield positive results when dyed with reactive dye in a single bath. Visual assessment confirms the favorable outcome of this process. Moreover, the reflectance curve observed in the spectrophotometer exhibits a similar pattern for both the jute-cotton blended fabric and pure cotton fabric. In terms of dry rubbing fastness, the jute-cotton blended fabric demonstrates a comparable performance to the cotton fabric samples in terms of color change and staining on the grey scale. However, when it comes to wet rubbing fastness, the jute-cotton blended fabric falls one grade lower than the cotton fabric in terms of both color change and staining on the grey scale. Additionally, the wash fastness of the jute-cotton blended fabric is also one grade lower than that of the cotton fabric. Taking into account the reflectance curve, wash, and rubbing fastness of this particular sample of jute-cotton blended fabric, it can be concluded that it is suitable for dyeing using a single-stage method and can be utilized in the production of diverse products. Nevertheless, further investigation involving the variation of different parameters will be necessary to make informed decisions in the field.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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