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Dye Extraction from Mango Peel and Dyeing of Cotton, CVC and Viscose Fabric Using Extracted Mango Peel Dye and Natural Mordant

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ABSTRACT

Natural dyes are environmentally suitable due to their ecology and minimum impact on the environment and pollution. It can be a substitute for chemical dyes, which have some serious concerns about the environmental impact. The objective of this study is to extract natural dyes from mango peel and apply them on three different fabrics (cotton, chief value cotton, and viscose) to compare which fabric is more suitable. Tannin extracted from tea leaves was used as a natural mordanting agent. Both dye and mordant were extracted using a hot aqueous extraction method. Results show that mango peel dye can be an effective and sustainable alternative to synthetic dyes with promising potential for application in textile processing. Moreover, the tannin extracted from tea leaves enhanced the dye's adherence to all three fabric types, which shows good color fastness and durability.

Keywords: Natural dye, CVC Fabric, Natural Mordant, Mango peel.

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1. INTRODUCTION

Dye is a chemical that is used to color fabrics, paper, leather, and other materials in such a way that the coloring is not easily affected by washing, heat, light, or other elements. The majority of dyes are organic compounds (i.e., they include carbon). The textile industry has long been a major contributor to environmental pollution due to the extensive use of synthetic dyes and chemical mordants. The effluent generated by the dyeing industry with much water would pollute the environment. The toxic waste created by synthetic dyes, including hazardous effluents, poses considerable environmental risks, including water contamination, releasing harmful chemicals and heavy metals into water bodies, which affect aquatic ecosystems and human health, and soil degradation [2]. The textile industry has depended on synthetic dyes for a long time due to their affordability and ability to produce a wide range of colors. But the environmental impact of the synthetic dyeing process has become a serious threat. Awareness of these environmental issues is rising; the interest in natural dyes has increased. Recently there has been a growing interest in sustainable and eco-friendly alternatives that can minimize environmental impact while maintaining the qualities of dyed fabrics. Natural dyes, derived from plant sources, present a promising solution by offering vibrant colors without the adverse environmental effects of synthetic dyes. Apart from their application in textiles, natural dyes are also used in the coloration of food, medicines, handicraft items, and toys and in leather processing [3].

The performance of natural dyes varies based on the type of fabric used. Cotton is popular in natural dyeing studies because of its cellulose-based structure. It is known for its good absorbency and affinity for natural dyes, especially when used with an appropriate mordant [4]. There is comparative research on dye staff extraction from ash tree bark and leaves, shiso leaves, henna leaves, eucalyptus leaves, orange peel, and pomegranate peel, as well as evaluation of dye quality, application of dye on fabric, and related other parameters, including environmental concerns [5].

As per study on pomegranate peel research, dyestuff extraction from the pomegranate peel was applied as a potential source of a synthetic dye. It is a first step to investigate the Tencel fabric samples through pomegranate peel dye [6]. Mango bark has been reported to be used on silk and cotton materials as a source of natural dyes, and a wide range of colors have been produced using different mordants [7]. Progress has been made with the study in the use of extracted dye from mango leaves. It has a good scope for application on silk fabrics. Single and combined synthetic mordants were used for different color shades [8]. An aqueous extraction method was used for the extraction of dye from orange peels and applied to lyocell fabric with $FeSO_4$ & $CuSO_4$ as mordants. Aqueous extraction technique was also used for dye extraction from mango leaves and mango peels [9].

Mango peel is an abundant agricultural byproduct, and it is frequently discarded as waste. However, its inherent pigmentation presents an opportunity for sustainable dyeing practices. Utilizing this resource not only addresses waste reduction but also capitalizes on its rich color-producing properties. Mango peel is an agricultural byproduct that has recently gained attention for its potential as a natural dye source. Mango peels are commonly discarded as waste. But they contain natural pigments such as flavonoids and polyphenols, which can produce color when extracted. Studies have shown that the extraction of dye from mango peel using aqueous methods produces good results by producing yellow to orange colors that can be applied to many textile fibers [10]. It was discovered that the dyes taken from mango peel and leaves worked well as coloring agents when applied to cotton textiles. Mango leaves and mango fruit peel are two distinct natural sources from which dyes have been derived. More coloring material is present in dyes made from mango leaves than in colors made from mango peels. All of the dyes derived from different portions of the mango plant were successfully used to dye cotton fabric.

Many researchers have explored that mango peel can be used as a natural dye. It can be applied to different types of fabrics [11]. The study shows that it can achieve good color strength and fastness properties if appropriate mordants are used. Shahid et al. found that fruit waste, including mango peel, can provide a sustainable source of natural dyes. The most challenging part of natural dyeing is ensuring the dye's adherence to the fabric. Mordants play an essential role in this process. Mordants are the substances that bind the dye to the fabric. There are many traditional mordants, such as alum, copper sulfate, and chromium salts, but those are chemical-based and pose environmental hazards similar to synthetic dyes. But natural mordants, which are derived from plant sources, are being researched as eco-friendly alternatives [12].

Tannins are widely recognized for their strong binding properties. It is a class of polyphenolic compounds found in many plants. Tea leaves are a rich source of tannins and have been used in textile dyeing for their ability to improve color fastness [13]. Studies have found that tannins from tea leaves act as effective mordants for natural dyes. It enhances the dye fixation to fibers and improves resistance to fading [14]. A study conducted by Pervaiz et al. found that tea tannin was used as a mordant with various natural dyes. It shows significant improvements in the durability of the dyed fabrics [15].

Previous researchers only used synthetic mordants in dyeing with natural dyes. However, this study explores the potential of mango peel as a natural dye to find out the dyeing potential of mango peel on cotton, chief value cotton (CVC), and viscose fabrics while optimizing dyeing parameters such as pH, dye concentration, and mordanting methods. To enhance the dyeing process, tannin extracted from tea leaves was employed as a natural mordant to find out how effective mango peel is when used with tannin extracted from tea leaves as a natural mordant in terms of color depth and fastness properties.

2. METHODOLOGY

2.1 Materials

Three different fabrics (100% grey cotton fabric, 100% grey viscose fabric, and grey CVC fabric) were used for dyeing. These fabrics were collected from a commercial textile mill in Bangladesh (Fig. 1).

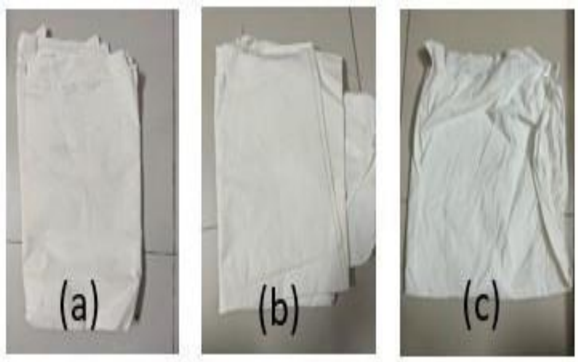


Fig.1. Grey Fabrics, Cotton (a), CVC (b) Viscose (c)

2.2 Mango peel powder

Mango peel was extracted from ripe mangos, and the extracted peels were dried for 3 days in the heat of the sun. By using a home blender machine, the peels were triturated. The weight of the powder was 200 g (Fig. 2).

Fig.2. Dried Mang Peel (a), Mango Peel powder (b).

2.3 Extraction of dye from powdered mango peel

2 liters of water were taken in a medium-sized pot. 200g of mango peel powder was added inside the pot. Then the pot was placed above a burner. The temperature of the mango peel powder solution was monitored by using a thermometer. A constant 100°C was maintained for 1 hour. The solution was then filtered by using a 100% viscose fabric. The filtered solution was measured, and 500mL of dye solution was obtained (Fig.3).

Fig.3. Dye Extracted from Mango peel.

2.4 Extraction of tannin from tea leaf

Black tea was used for this experiment. 500 mL of water was taken in a pot, and 50 g of black tea leaf was added into it. The pot was placed above a burner, and the temperature was monitored by using a thermometer. A temperature of 60° was maintained for 10 minutes. The offscourings of the tea leaves were separated by using 100% viscose fabric. The remaining tannin was measured, and 300 mL of solution was obtained. Black tea was use for this experiment. 500mL of water was taken in a pot and 50g of black tea leaf was added into it. The pot was placed above a burner and temperature was monitored by using a thermometer. 60° of temperature was maintained for 10 minutes. The offscourings of the tea leaves was separated by using 100% viscose fabric. The remaining tannin was measured and 300mL of solution was obtained (Fig.4).

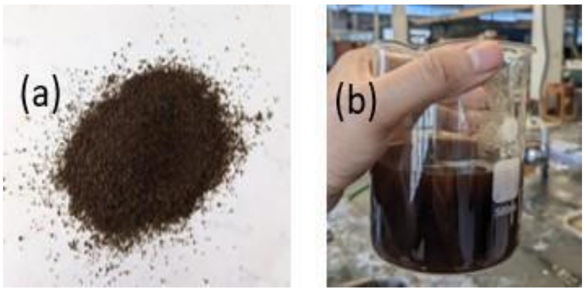


Fig.4. Extraction of Tannin. Tea Leaves (a), and Tannin extracted from tea leaf (b).

2.5 Pre-treatment of Fabrics

The gray fabric of cotton, viscose, and CVC was pre-treated by doing scouring and bleaching. All three of the gray samples were taken in a pot. After adding necessary chemicals, the pot was taken on a burner, and a constant 100°C temperature was maintained for 45 minutes. Details of the pre-treatment process are mentioned in Table 1.

Table 1: Pretreatment Process Parameters

Parameters	Value
Detergent	1 g/L
Caustic Soda NaOH	3 g/L
Hydrogen per oxide (H_2O_2)	5 g/L
Stabilizer	2 g/L
Sequestering agent	0.7 g/L
Time	45 min
Temperature	100^0C

2.6 Dyeing of the pretreated samples with mango peel extracted dye

All three of the scoured-bleached samples were rinsed with tap water and put into a 500 mL mango peel extracted dye solution. The pot of the dye solution was taken on a burner and heated for 60 minutes at 60°C temperature. The fabrics were rinsed with tap water to wash away unfixed dyes. Parameters of the dyeing process are mentioned in Table 2.

Table 2: Dyeing Process Parameters

Parameters	Value
Mango peel Extracted dye	44.42% o.w.f
Tea Leaf extraction	17.77% o.w.f
Acetic Acid	1g/L
pH	6
Time	80 min
Temperature	100^0C

2.7 Application of Tannin to Dyed Fabrics

300 mL of tannin was taken in a pot, and dyed fabrics were added into the batch. The temperature of 60°C is maintained throughout the process, and the process has taken 10 minutes of time. Curing was done at a 150°C temperature for 2 minutes. The tannin was used in another step because the shade of the fabric needed to be determined after dyeing with the mango peel extracted dye. That's why mordanting and dyeing were done in different steps.

2.8 Finishing Process of the Dyed Fabrics

The fabric was washed with detergent at normal temperature to remove unfixed tannin and dye. The fabrics were dried with an air dryer for 10 minutes.

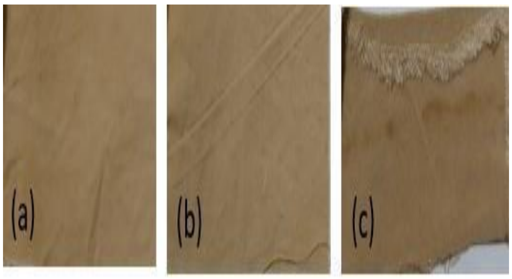


Fig.5. Mango peeled extracted Dyed Fabrics (a) Cotton (b) CVC and (c) Viscose.

2.9 Measurement of Color Fastness

The test follows the ISO 105 X12:2016 standard. This test is performed under both dry and wet conditions. Color fastness to washing test is done to determine how well a dyed fabric resists color loss when subjected to washing conditions. The test follows the ISO 105 C06:2010 standard for textiles and is performed under specified conditions, including detergent, temperature, and washing time.

2.10 K/S Measurement by spectrophotometer:

K/S (Kubelka-Munk Function) was measured by spectrophotometer. K/S values were measured across wavelengths of 400 nm, 500 nm, 600 nm, and 700 nm.

3. RESULT & DISCUSSION

3.1 Color Fastness to Rubbing

Color fastness to rubbing test evaluates how much color is transferred from the surface of a dyed fabric to another surface when rubbed. It reflects how resistant the dye is to abrasion and friction. The rubbing test evaluates the degree of color transfer from fabric to a white testing fabric when rubbed under both dry and wet conditions. This test determines the durability and usability of the dyed fabric when the product will experience frequent contact and friction. Fig. 6 shows the color fastness to rubbing test results for three fabrics.

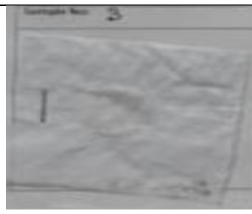
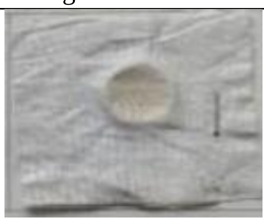
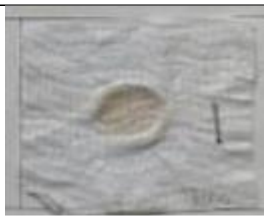
Test	Cotton	CVC	Viscose
Dry rubbing	 Rating 4-5	 Rating 4-5	 Rating 4-5
Wet rubbing	 Rating 3-4	 Rating 3-4	 Rating 3-4

Fig. 6. Color fastness to rubbing of three dyed fabrics.

The results are graded based on the amount of color transferred on a scale from 1 to 5. 1 indicates heavy staining, and 5 indicates no staining. All dyed fabrics showed excellent color fastness under dry conditions by scoring 4-5. This ensures that the natural dye extracted from mango peel and tannin as a mordant is well-fixed to the fabric with minimal color transfer under dry friction. For most end-use applications, a score of 4-5 is satisfactory when the products are less likely to be exposed to wet conditions during use. The performance of the fabrics under wet conditions was slightly reduced. It showed a score of 3-4. Wet rubbing increases the color transfer because the moisture can weaken the bond between the dye and the fabric, while the performance is still acceptable because a score of 3-4 indicates moderate fastness. The reduction in fastness under wet conditions raises some concerns for fabrics intended for high-moisture environments.

3.2 Colorfastness to wash

Color fastness to wash determines how well the fabric's color resists fading during laundry, which evaluates the ability of dyed fabrics to keep their color after washing at a specified temperature. The color fastness to washing test assesses both the color change of the test fabric itself and the staining it causes on adjacent fabrics. Both color change and staining are rated on a scale from 1 to 5 using grey scales. The standard requires testing the fabric against multiple adjacent fabrics to determine the degree of staining on those adjacent fibers. In this wash fastness test, three samples were evaluated against six adjacent fibers: acetate, cotton, nylon, polyester, acrylic, and wool. Table 3 shows the color fastness to wash for three fabrics. In this wash fastness test for three samples were evaluated against six adjacent fibers: acetate, cotton, nylon, polyester, acrylic, and wool. Table 3 shows the color fastness to wash for three fabrics. The image of the color fastness to wash for three fabrics is shown in Fig. 7.

Table 3: Color fastness to wash (Staining)

Fabric	Acetate	Cotton	Nylon	Polyester	Acrylic	Wool	Color change
Cotton	4-5	4-5	4-5	4-5	4-5	4-5	3-4
CVC	4-5	4-5	4-5	4-5	4-5	4-5	3-4
Viscose	4-5	4	4	4	4	4	3-4

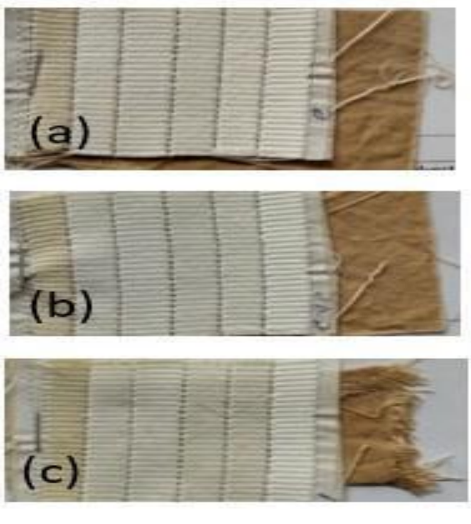


Fig. 7. Color fastness to wash of three dyed fabrics, (a) Cotton (b) CVC and (c) Viscose.

All three fabrics show excellent performance in the wash fastness results for staining on acetate, cotton, nylon, polyester, acrylic, and wool with most adjacent fibers scoring 4-5. This indicates that there was very minimal to no staining on adjacent fibers during washing. That means the dye adhered well to the fabric without bleeding significantly.

For viscose fabric, the staining results slightly decrease to a score of 4 for nylon, polyester, acrylic, and wool. Though it is still within an acceptable range but this minor reduction indicates a slight tendency of the dye to transfer to these fibers under washing conditions. The color change for all three fabrics was consistently rated 3-4. This indicates moderate to good resistance to fading. The color loss observed after washing shows that the dye is not fully stable under washing conditions and some fading does occur. A color change score of 3-4 is acceptable for many applications, but for fabrics that require high durability.

3.3 K/S Parameters and CMC of Dyed Fabrics

K/S measures color strength and depth of color. Commonly used to assess dye uptake and shade depth on fabrics. The K/S value helps in understanding how well the dye has been absorbed by the fabric. K/S results of three dyed fabrics are shown in Table 4.

Table 4: Color fastness to wash (Staining)

Wave length (nm)	Cotton (K/S)	CVC (K/S)	Viscose (K/S)
400	Highest values, indicating deep color strength	Lower values than Cotton, but closer to it at higher intervals	Generally highest across intervals, showing the most intense color depth
500	Moderate color strength	Similar to Cotton, but slightly lower	Higher than both Cotton and CVC, especially at higher intervals
600	Moderate to low color strength	Similar trend to Cotton but slightly lower values	Highest, showing deeper color penetration
700	Lowest color strength	Similar trend to other Fabrics but lower overall	Highest values, indicating deeper color in the red spectrum

Viscose dyed fabric demonstrates the highest overall K/S values, indicating the deepest color depth and strongest dye uptake, making it the most vibrant of the three samples. Cotton dyed fabric has a moderate dye uptake, showing a strong color in the blue region but weaker in the red. CVC dyed fabric has the lightest color strength, slightly lower than cotton, and does not achieve high saturation at any wavelength. For applications requiring intense and saturated colors, viscose dyed fabric would be the preferred choice due to its high K/S values, suggesting optimal dye penetration. In contrast, cotton and CVC dyed fabrics could be better suited for lighter shades.

The CMC (Color Measurement Committee) values provide insights into the color differences between each fabric under different illuminants (D65-10, TL84-10, A-10) and color coordinates (L*, a*, b*, C*, h*). The values of ΔL*, Δa*, Δb*, ΔC*, and ΔH* indicate the variations in lightness, red-green, yellow-blue, chroma, and hue, respectively. These differences are essential for understanding the quality and consistency of dye application across the dyed fabrics. CMC values of three dyed fabrics are shown in Table 5.

Table 5: CMC values of three dyed fabrics.

Parameters	**Cotton**	**CVC**	**Viscose**
D65-10	L* = 67.48 a* = 6.59 b* = 19.18 C* = 20.27 h* = 71.05	L* = 68.63 a* = 5.96 b* = 18.40 C* = 19.34 h* = 72.05	L* = 66.40 a* = 7.53 b* = 23.15 C* = 24.34 h* = 71.98
TL84-10	L* = 68.68, a* = 6.44, b* = 21.79, C* = 22.73, h* = 73.54	L* = 69.77 a* = 5.89 b* = 20.92 C* = 21.73, h* = 74.27	L* = 67.81, a* = 7.28, b* = 26.26, C* = 27.25, h* = 74.51
A-10	L* = 69.42, a* = 10.43, b* = 21.33, C* = 23.74, h* = 63.94	L* = 70.46, a* = 9.68, b* = 20.40, C* = 22.57, h* = 64.61	L* = 68.64, a* = 11.81, b* = 25.86, C* = 28.16, h* = 65.21

Cotton dyed fabric shows a moderate increase in lightness (L*) and chroma (C*) under different illuminants, suggesting stable coloration under varying light sources. However, the hue (h*) shifts slightly, indicating potential sensitivity to lighting conditions. CVC dyed fabric maintains higher lightness (L*) and chroma (C*) values across all light sources compared to Sample 1, but the hue (h*) changes more significantly, indicating more noticeable color changes under different lighting. Viscose exhibits the highest chroma (C*) values, indicating a more vivid color under each illuminant. The lightness (L*) is lower than the other samples, making this sample appear slightly darker. However, the hue shift is pronounced, which may affect color consistency under varying light. The color consistency of cotton is relatively stable in terms of hue, but CVC and viscose exhibit more significant changes under different lighting, with viscose being the most sensitive. Chroma (C)** of viscose has the highest chroma values, indicating a more intense color, while cotton has the lowest, potentially due to differences in dye concentration or fabric interaction. Lightness (L)** of CVC is the lightest, while viscose appears the darkest, which could impact visual perception in practical applications.

4. CONCLUSION

This study highlights the potential of using natural dyes extracted from organic waste like mango peels as a sustainable alternative to synthetic dyes. By applying the dye to cotton, CVC, and viscose fabrics. This study shows that natural dyes can produce colors with satisfactory fastness properties when combined with a natural mordant such as tannin extracted from tea leaves. The use of tannin as a mordant enhances dye fixation while maintaining eco-friendly dyeing practices. The findings suggest that by optimizing dyeing parameters like dye concentration, pH levels, and mordanting methods, natural dyes can offer comparable performance without the environmental hazards. Moreover, this study contributes to the ongoing effort to reduce waste and promote sustainability in textile manufacturing by utilizing waste like mango peels. Future studies could explore the long-term durability of these dyes under different environmental conditions and further optimize the processes for bulk production.

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