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Eco-Friendly Dyeing of Cotton Fabric with Vat dyes

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ABSTRACT

Vat dye is very popular dye staff used for coloration of cotton, particularly when high fastness is required. During vat dyeing a reducing agent is required for vatting process. In this study the conventional reducing agent sodium hydrosulphite (Na2S2O4) have replaced by palm wine as the green method during dyeing of vat dyes on cotton fabrics. Eco-friendly vat dyeing with palm wine increased the color strength (fk) and colorfastness properties of the dyed fabrics. The Green dyeing process of vat dyes with palm wine enhanced bursting strength and pilling resistance rather than hydrose. BOD, COD, TDS, pH values were measured to indicate the environmental impact due to different reducing agent.

Keywords: *Vat dye, Sodium hydrosulphite, Palm wine, f_k value, Color fastness*

INTRODUCTION

Vat dyes are most important dyes for dyeing and printing on cotton fibers. They have excellent colorfastness properties which includes-washing, light, perspiration and rubbing fastness [1]. The dye has the problem of insolubility in water. Hence the process of vatting is needed to reduce and solubilize the dye in water. Reducing agent, such as sodium hydrosulphite (Hydrose) is used for reduction and sodium hydroxide for solubilization. The use of sodium hydrosulphite is not friendly for the environment as it decomposes sulphite, sulphate, thiosulphate and toxic sulphur [2]. Therefore, several attempts are being made to create alternate for the hydrose that cause less damage to the environment. The present study is carried out to see the effect of palm wine as reducing agent on textile material. The results of dyeing using palm wine as reducing agent have been compared with dyeing with hydrose.

2. EXPERIMENTAL:

2.1 Material:

Scoured & bleached (100%) cotton single jersey fabric (160 g/m^2) was obtained from Square Textile Mills Ltd (Dhaka, Bangladesh). The Vat dye (C.I. Solvent Blue 35) and sodium hydrosulphite were kindly supplied by BASF (Dhaka, Bangladesh). Eco-friendly reducing agent palm wine was manufactured from palm juice kept under dark conditions for 30 days. All other reagents were laboratory reagent grades.

2.2 Dyeing Procedure:

A 50 ml dye bath, suitable for 2 g scoured & bleached cotton (liquor ratio 1: 20) containing vat dye (C.I. Solvent Blue 35) (2% owf), NaOH (2.0g/l) and reducing agent was prepared. Dyeing was performed for 45 min at 70^o C in a laboratory AHIBA IR dyeing machine. For selection of reducing agent hydrose and palm wine was used. After dyeing, all the samples were oxidized for 3 hours in air and then it was rinsed properly with detergent. The color strength (f_k) values of the dyed fabrics were measured using a spectrophotometer (Data Color 650).

2.3 Color Evaluation:

The color strength (f_k) values of the dyed fabrics were measured using a spectrophotometer (Data Color, standard light D_{65}, 10^o standard observer, λ =540 nm) interfaced with a personal computer. Where, K= Coefficient of absorption of dye at λ_{max}, S= Coefficient of scattering at λ_{max}, R= Reflectance of the specimen at λ_{max}.

$$K/S = (1-R)^2/2R \quad (1)$$

The color strength (f_k) is the sum of the weighed K/S values in the visible region given by:

$$f_k = \sum_{\lambda=400}^{700} \left(\frac{K}{S}\right)_\lambda \left(\bar{x}_{10,\lambda} + \bar{y}_{10,\lambda} + \bar{z}_{10,\lambda}\right) \quad (2)$$

Where $X_{10\lambda}$, $Y_{10\lambda}$, $Z_{10\lambda}$ are color matching functions for the 10^0 standard observer at each wavelength (ISO 7724/1-1984). The color differences (ΔE_{ab}^*) between the standard and another fabric are:

$$\Delta E_{ab}^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (3)$$

2.4 Color Fastness:

Color fastness was assessed by international standards. For the wash fastness ISO 105-C01, alkaline and acid perspiration were checked by ISO 105-E04 and color fastness to rubbing was measured by ISO 105 X 12. For color fastness to water test ISO 105-E01 was used.

2.5 Fabric Strength:

Normally fabric strength decreases after different processing. SDL Atlas M299P machine was used to determine bursting strength of dyed fabric. ISO 13938–1:1999 method was used for determining fabric strength.

2.6 Effluent load from dye solution:

The effluent parameter such as total dissolved solid (TDS), pH, biological oxygen demand (BOD), chemical oxygen demand (COD) were tested from effluent load of vat dyed bath with different reducing agents.

3. RESULTS AND DISCUSSION:

3.1 FT-IR and NMR analysis of palm wine:

The FT-IR spectra in Figure 1 of the Palm wine showed strong band within the range 3367.71 cm^{-1}, 1611.42 cm^{-1} and 1282.66 cm^{-1} corresponding to hydroxyl (-OH), carbonyl groups (-C=O) and (-C-O) respectively. It can be suggested that these compounds exist in palm wine.

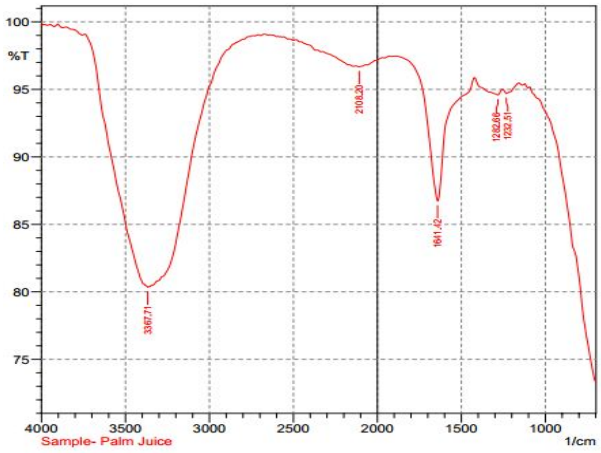


Fig 1: The FT-IR spectra of palm wine

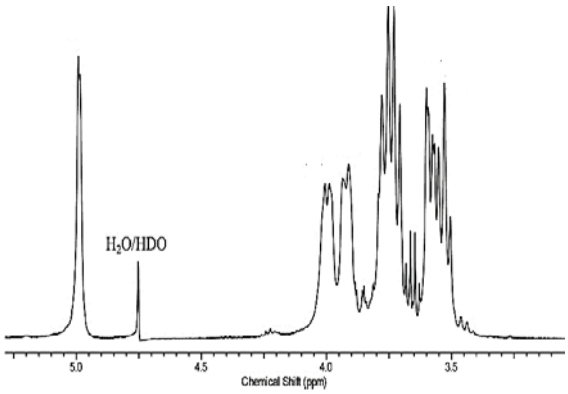


Fig 2: The H-NMR spectra of palm wine

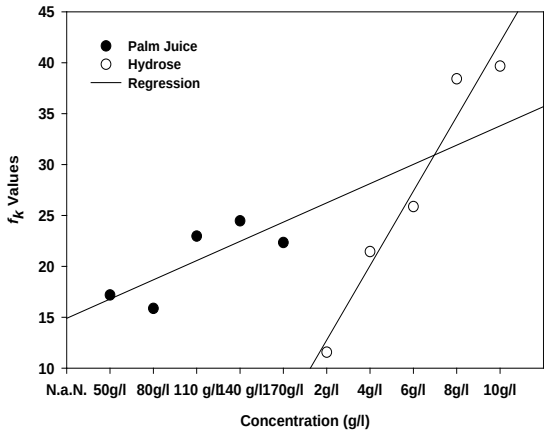


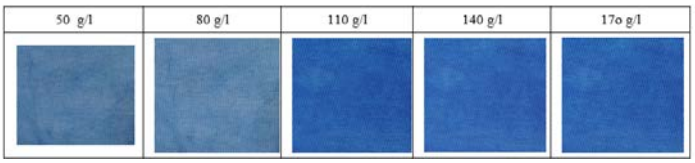
Fig 3: Effect of concentration of reducing agent on color strength.

The H-NMR spectrum of palm wine is presented in Figure 2. The spectrum contains singlets at δ 5.41 for the CH_2 groups. The H peaks at δ 3.50 and 3.52 ppm arise from $H_{5,\ 3,4}$. Peaks at δ 3.66 and 3.76 ppm are attributable to H_2 and H_4.

3.2 Color strength:

In the figure 3, it is clearly seen that color strength of fabric (f_k) varies with different concentration of palm wine and hydrose. From the regression analysis of figure 3, it is seen that at 50g/l of palm juice f_k value is 17. The value normally increases with higher concentration. But after 140 g/l the value starts to decrease. At 140g/l f_k value is at peak point (24.5), whereas at 170 g/l it shows f_k value of 22.

On the other hand, color strength gradually increases by using 2g/l, 4g/l, 6g/l, 8g/l, 10g/l of hydrose (figure 3). From industrial point of view 6g/l hydrose is suitable for reducing vat dye solution and also suitable for cost minimization. It is clear that



highest pick of f_k value was obtained by using 140g/l palm wine, which is equivalent to using of 6g/l hydrose as reducing agent.

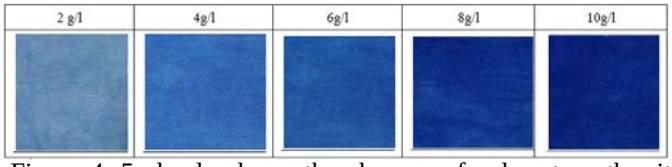


Figure 4, 5 clearly shows the changes of color strength with different concentration of palm wine and hydrose. It is seen that 10 g/l of hydrose gives highest depth of shade but this is not used practically as high concentration of hydrose reduces fabric strength [3]. All the performance tests were done on dyed fabric using 140 g/l palm wine and 6g/l hydrose to evaluate dyed fabric quality.

Fig 4: Effect of various palm wine concentration on the depth of shade of cotton fabric

Fig 5: Effect of various hydrose concentration on the depth of shade of cotton fabric

3.3 Color Fastness:

Color fastness properties of dyed fabric using different form of reducing agents (Palm Juice 140 g/l, Hydrose 6 g/l) are given in Table 1. Good fastness properties were obtained using both reducing agents. Wet rubbing fastness using palm wine as reducing agents showed good rating compared to dyed fabric using Hydrose.

Table 1: Effect of Different Reducing Agents on Color Fastness Properties

Color Fastness test	Dyeing with hydrose	Dyeing with palm wine
Wash fastness	4-5	4-5
Water fastness	4-5	4-5
Perspiration (Alkaline) fastness	4-5	4-5
Perspiration (Acid) fastness	4-5	4-5
Rubbing fastness	Dry Rubbing 4-5, wet rubbing 3-4	Dry Rubbing (4-5), wet rubbing (4)

3.4 ICI Pilling test:

Pilling properties of fabrics using different reducing agents (Hydrose 6 g/l, Palm wine 140 g/l) are given in Table 2. Good results were obtained from both cases. The results were taken after 14400 cycles.

Table 2: Effect of Different Reducing Agents on Pilling Properties

Used reducing agent	Rating
Palm wine	4-5
Hydrose	4

3.5 Bursting Strength Test:

Fabric strength reduces after both the processes. It can be seen from the graph that, palm wine decreases the strength of the fabric lesser than the hydrose.The Strength properties of vat dyed cotton knit fabric using different form of reducing agents (Hydrose 6 g/l, Palm wine 140 g/l) are given in figure 6.

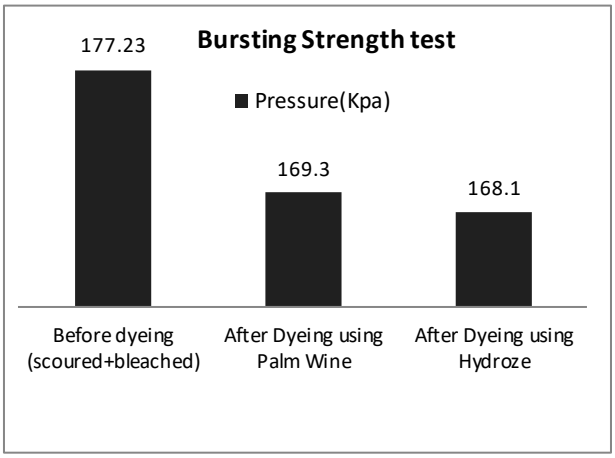


Fig 6: Effect of different reducing agents on bursting strength

3.6 Effluent from dye solution:

Figure 7 shows residual dye bath BOD value with different reducing agent. Eco-dyeing process with palm wine shows low BOD value than the dyeing process with hydrose. Because of using palm wine BOD value was seen to be reduced by 83.54%.

Dye bath pH after dyeing is also low for using palm wine as reducing agent (figure 8). And the condition is alkaline,which is very essential for vat dyeing process. pH value is 0.3 less for dyed solution with palm wine.

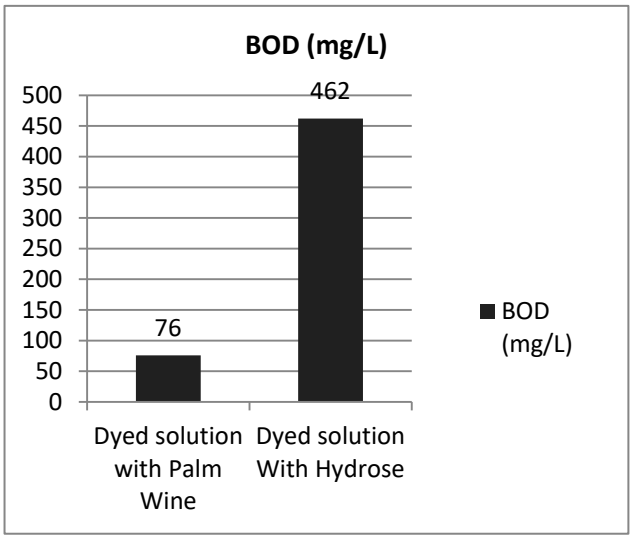


Fig 7: BOD values of residual dyed solution

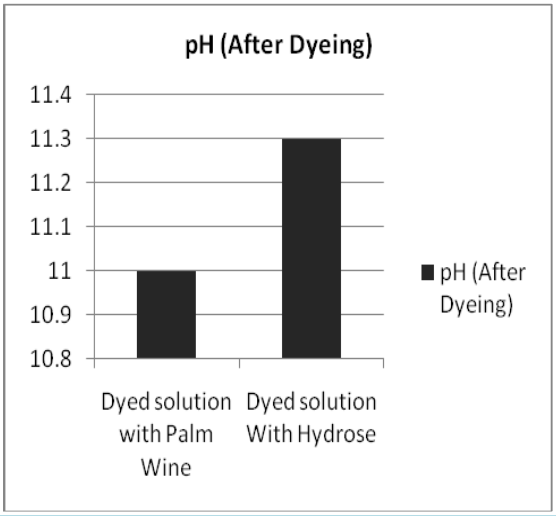


Fig8: pH values of residual dyed solution In

In figure 9 it is seen that, total dissolved solid value of residual dye bath is lower for solution with palm wine than the solution using hydrose. TDS value is 36.84% lower for solution with palm wine than using hydrose. This increased TDS value causes environmental hazard and pollution and also costs more for treatment of effluent. Chemical oxygen demand or COD value is also higher for the solution using hydrose than palm wine. Due to hydrose, COD value increase a great amount and it was more than 5 times higher than using palm wine. A comparative value can be seen for COD values at figure 10. COD value was seen to be reduced by 81.28% for using palm wine.

Fig 9: TDS values of residual dyed solution

Fig 10: COD values of residual dyed solution

CONCLUSION:

From the above discussion, it can be stated that using palm wine as reducing agent is more eco-friendly than hydrose. BOD, COD, pH, TDS values are lower when palm juice was used as reducing agent. Because of using palm wine BOD value was seen to be reduced by 83.54%. pH value was found 0.3 less for dyed solution with palm wine. TDS value was found 36.84% lower for solution with palm juice than using hydrose. COD value was found 5 times lower than using hydrose. Dyed fabric using palm wine also shows better bursting strength than using hydrose. Color fastness properties are almost same for using both reducing agents. But wet rubbing fastness increases when palm wine is used. Color strength can be reached to a certain limit by using palm wine. But this range is commercially popular. On the other hand, hydrose can give more range of color with high concentration. But using high concentration of hydrose is not commercially feasible as it reduces fabric strength more with increasing concentration of hydrose.

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