International Journal of Science and Research (IJSR)
ISSN: 2319-7064
Impact Factor 2023: 1.843

Comparitive Study on Application of Homo - Bifunctional Reactive Dye on Different Cellulosic Fibres and its Colour Characterization

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Abstract: ***Present research aims at the comparative study of the colour characterization of different cellulosic fibres dyed with homo - bifunctional reactive dye. Bifunctional dyes have enhanced fastness, faster washing off, and application across a larger temperature range. In addition to that, these dyes gave considerably good substantivity and exhaustion values. This strategy reduced the amount of colour in the effluent by improving colour use. Bright and deep hues are produced by bi - functional reactive dyes because they tend to be highly soluble and have good levelling capabilities. Both the cellulosic fibres namely, cotton and viscose rayon were dyed under similar processing conditions and then evaluated for their colour strength and fastness properties. Better exhaustion results were obtained for viscose rayon as compared to cotton fabric.***

Keywords: homo- bifunctional reactive dye, cotton, viscose rayon, colour strength

1. Introduction

The most important event in the history of reactive dyes was introduction of reactive dyes for cellulose by ICI in 1954. When water - soluble dye containing a dichlorotriazine (DCT) group is applied to cellulose from a neutral bath and then increasing the pH value, a covalent bond is formed between a triazine carbon atom and an oxygen atom of a cellulose hydroxyl group. Due to incomplete utilization of the dye bath (i. e.60 - 70% exhaustion and 30 - 40% hydrolysed dye still remain in the bath) and also due to low fixation property, compared to modern multi - functional dyes, these dyes show poor washing off and effluent related problems. This led to the manufacturing of monochlorotriazine dyes (MCT) (Mahapatra, 2016; Kaur & Saini, 2019). Ciba manufactured monochlorotriazine dyes (MCT) or amino chlorotriazine, which can be applied on cellulose at higher temperature and pH. In the beginning of 1970 a new era began in the innovation of reactive dyes i. e. bi - functional reactive dyes. Homogeneous and heterogeneous bi - functional reactive dyes were introduced by many dyestuff manufacturers with suffix HE or ME or XE. A major development from the 1970s onwards was bi - functional reactive dyes (Taylor, 2000). The idea behind bi - functional (and tri/tetra functional) dyes was to produce a range of high temperature dyes for exhaust application with increased substantivity, exhaustion and fixation values compared with the dyes containing only one reactive group. A bi–functional dye is one carrying two reactive groups. The groups could be similar (Homo bi - functional) or dissimilar (hetero bi–functional/mixed bi–functional). The mid - 1980s saw a renewed focus on homo - bifunctional types, with additional research being done on items based on bis - vinylsulphonyl and bis monochlorotriazinyl (Khatri, Akhtar & Ahmad, 2020). Additional benefits of combined bi functional dyes include enhanced fastness, faster washing off, and application across a larger temperature range. It is currently offered for sale by over 50 dye makers and is distinguished by its superior economy, high fixation, and variety of application. These H - E dyes were designed to considerably outperform comparable products with a single chlorotriazinyl group in terms of fixing and substantivity exhaustion values. This strategy reduced the amount of colour in the effluent by improving colour use (Hunter & Renfrew, 1999; Chakra borty, 2004).

Cotton is used as textile fibre from the beginning of our modern civilization and a wide range of apparels are produced from cotton fibers. The demand for cotton is increasing day by day due to its unique comfort ability. It has low thermal conductivity, and strength, moisture absorption, wicking properties, beautifulness, and availability around the world. Cotton is the purest form of cellulose found in nature, is the seed hair of plants of the genus Gossypium. Cellulose is an organic compound with the formula $(C6H10O5)$ n, a polysaccharide consisting of a linear chain of several hundred to over ten thousand β (1→4) linked D - glucose units. For dyeing of cotton goods, reactive dyes are so much suitable and extensively used in the textile dyeing industries. Rayon is the oldest commercial man - made fibre. It is a manufactured fibre composed of regenerated cellulose in which substituents have replaced not more than 15% of the hydrogens of the hydroxyl groups. Being a cellulosic fibre, its properties are similar to those of cotton (Table 1 & 2). It is highly absorbent, soft and luxurious, wrinkle free and easy to dye (Khan, Khan, Rahman, & Hossain, 2018; Hasan & Hossain, 2020).

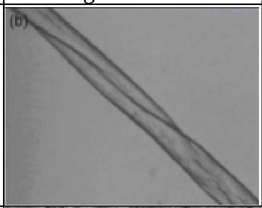
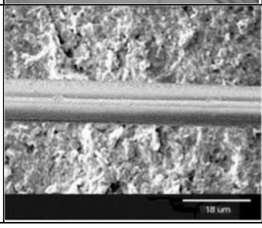
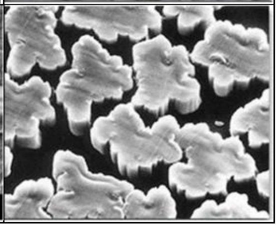
Table 1: Comparison of physical properties of cotton and viscose rayon

Physical properties	Cotton	Viscose rayon
Tenacity (g/d)	3.3 - 6.4	0.5 - 0.8
Elongation at break (%)	6.8 - 8	3.0
Moisture regain (%)	7	12.5

Density (g/cm^3)	1.52	1.51

The dyeing of these fibers is generally done with reactive dyes due to its brilliancy, variety of hue, high wet fastness, and versatile applicability. Dyeing of reactive dyes depend upon various parameters like electrolyte, alkali, liquor ratio, pH of the dye bath and temperature. Generally, exhaustion of a reactive dye depends upon the amount of electrolyte and reactivity of a dye. The ionization of OH group in cellulose fibers is accelerated with an increase in pH, which favours their reaction with reactive dyes. (Gulrajani, 2019).

Table 2: Microscopic structure of cotton and viscose rayon

Fiber	Longitudinal view	Cross sectional view
Cotton		
Viscose rayon		

Reactive dyes react with the cellulosic fibre in the presence of alkali to form a strong covalent bond between a carbon atom of the dye molecule and oxygen atoms of the hydroxyl group in the cellulose. Salt is added to the dye bath to neutralize the negative charges on the fibre surface so that the dyes can diffuse more easily into the fibre (Hosseinnejad, Monjezi, Rahimi & Namazi, 2019). Once the dye molecules have been properly exhausted onto the fibre, alkali is added and the fixation of the dye molecules on the fibre takes place. Fixing agent is a cross - linking agent which would form a strong bridge between the cellulose and the dye, thereby anchoring the latter to the fibre (Gokarneshan, Vijayalakshmi & Ramakrishnan, 2012; Trotman, 1970).

Present study involves dyeing of cotton and viscose rayon by exhaust dyeing method using homo - bifunctional reactive dye and comparative analysis of colour strength and fastness properties for both the fibres.

2. Materials and Experimental Methods

Fibre: There are a number of things to take into account when choosing a cloth for dyeing, such as the fibre composition, weave, and finish (Table 3). The cotton fabric used in this investigation was purchased from local market Vadodara, Gujarat.

Dyestuffs: Reactive dye products belonging to various classes were acquired from a reputable chemical company called Colourtex Ind. Pvt. Ltd. In the current study, homo - bifunctional reactive dye (three primary colours) with high exhaust was employed (Table 4).

Table 3: Specifications of fibres used

Sr No.	Name of fiber	Whiteness index (ASTME 313)	GSM (grams per square meter)
1	Cotton	126.57	110
2	Viscose rayon	135.46	90

Table 4: Specifications of dyestuffs used

Dye Class	Homo - Bifunctional (High Exhaust) (HE)	Homo - Bifunctional (High Exhaust) (HE)	Homo - Bifunctional (High Exhaust) (HE)
Chemical Name	C. I. Reactive Red 120	C. I. Reactive Blue 172	C. I. Reactive Yellow 105
Commercial Name	Coracion Red HE3B	Coracion Navy Blue HE2R	Coracion Yellow HE4G
Reactive group	Two Monochlorotriazine groups	Two Monochlorotriazine groups	Two Monochlorotriazine groups

Auxiliaries: Chemical auxiliaries of the Laboratory Reagent (L. R.) grade were employed in this investigation. Table 5. has a report with all the chemical details.

Table 5: Specifications of auxiliaries

S. No.	Name of Chemicals	Chemical formula	Molecular weight (g/mol)
1.	Glauber's salt	$Na_2SO_4 * 10H_2O$	322.2
2.	Sodium Carbonate	Na_2CO_3	105.98
3.	Non - ionic Detergent	$C_{15}H_{24}O\ (C_2H_4O)_n$	573

Experimental Method

Prior to dyeing, cotton and viscose samples were given a hot wash. The dye bath was prepared for 3% owf (On weight of fabric) shade. The dyeing was carried out in open bath by the exhaust dyeing technique using following standard recipe (table 6) for both the fabrics.

Table 6: Standard recipe for exhaust dyeing method

M: L: R	1: 30
%Shade	3%
Glauber's salt (gpl)	40
Soda ash (gpl)	40
pH	10.7
Temperature (ºC)	90 - 95
Time (min)	45 - 60

All of the samples were dyed using the exhaust dyeing method in a water - heated dyebath in a laboratory. Utilizing HE dyes, dyebaths for all the samples were prepared. After 10 minutes of room temperature dying, the bath's temperature was gradually increased to 95ºC (Table 6). To help the colour run out, electrolyte or salt was applied after 15 minutes and left for 30 minutes. The dye bath must remain alkali - free until the dye is fully exhausted in order to prevent the dye from fixing too soon and causing uneven dyeing. As a result, alkali was added to the dye bath after 30 minutes to maintain the pH. After cooling the bath to room temperature and rinsing the samples under tap water, samples were then subjected to a 10 to 15 minute treatment at 60–70ºC using 2

Paper ID: SR241217105642 DOI: https://dx.doi.org/10.21275/SR241217105642

gpl non - ionic detergents to remove the hydrolysed unfixed dye from the fibre surface. The samples were then dried after receiving a thorough washing in cold water.

3. Testing and Analytical Methods

a) **Determination of colour strength (K/S):** Samples of cotton and viscose were dyed with reactive dye were assessed using a computer colour matching (CCM) system called the "Premier Colour Scan Spectrophotometer" (Model 5100). Different wavelengths of light are transmitted, scattered, and reflected differently by the coloured textile materials. The current analysis made advantage of this principle.
$K/S = (1 - R)^2 / 2R$
Where, K=Absorption Coefficient, S=Scattering Coefficient R=Reflectance.

b) **Determination of washing fastness (AATCC 61 - 1994 test method):** AATCC 61 - 1994 test method was used for the determination of washing fastness of dyed fabrics. Launder - O - meter is used for this purpose. The fabric to be tested of 10 × 4 cm was placed between two adjacent undyed fabrics of same size. Then sewed it along four side to form a composite specimen. The composite specimen was placed in a glass jar containing 5 g/l soap solution and 2 g/l soda ash solution, keeping material to liquor ratio 1: 50. Jars were then closed and placed in Launder - O - meter. Machine was then run for 30 minutes at 60 ± 2ºC temperature after completion of treatment, the samples were removed and washed with water, squeezed, and dried in air. By using Grey scale, the change in shade was assessed and graded from 1 to 5 (1 means poor and 5 means excellent fastness to washing).

c) **Determination of rubbing fastness (AATCC - 08):** A device used for the rubbing test has a finger of 1 - 6 cm diameter moving to and fro in a straight line covers a 10 cm track on the specimen with a force of 6N, a suitable apparatus is the crock - meter. The rubbing cloth against which the specimens were tested consist of desized, bleached and unfinished cloth cut into 10x10 cm size. Piece of material to be tested were prepared in two pairs of pieces not less than 15x15 cm^2, one for the dry rubbing and the other for the wet rubbing test. In both the cases, it travels 10 times in 10 seconds along the track. The staining of the rubbing cloth was assessed with grey scale and graded from 1 to 5 (1 means poor and 5 means excellent fastness to rubbing).

d) **Determination of light fastness (AATCC 16 - B 1977):** Colour fastness to light was evaluated by exposing the dyed samples to sunlight for 8 hours in a normal manner (according to AATCC test method 16 - B 1977) to see the effect of fading of colour due to sunlight. The light fastness properties were evaluated by comparison of exposed portion with the unexposed portion of the material. They were graded from 1 to 8 (1 means poor and 8 means excellent fastness to light) based on blue wool standard scale.

4. Result and Discussion

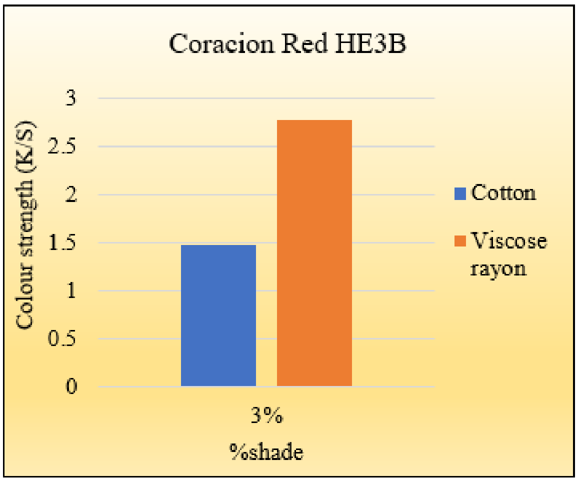
a) **Evaluation of colour strength (K/S) for dyed cotton and viscose rayon fabric:**

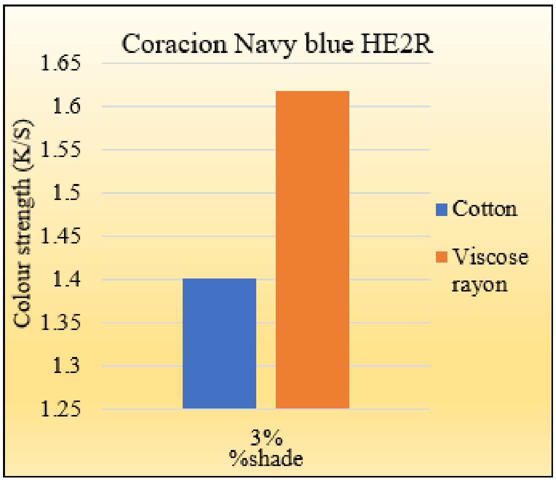
Colour strength of cotton and viscose rayon dyed with homo - bifunctional reactive dye was carried out on Premier Colour Scan Spectrophotometer (Model 5100) CCM system. Samples dyed with 3% shade and were assessed in this CCM system. Results obtained are as follows: (Table 7.)

Table 7: Colour strength comparison for cotton and viscose rayon

Name of Dye	Colour strength (K/S)	
	Cotton	Viscose rayon
Coracion Red HE3B	1.489	2.777
Coracion Navy Blue HE2R	1.402	1.671
Coracion Yellow HE4G	5.526	5.992

Soda ash being suitable alkali gives excellent depth of shade in three different concentrations of alkali in dyebath. Soda ash changes the pH of the fibre - reactive dye and cellulose fibre that the dye reacts with the fibre making a permanent connection that holds the dye to the fibre. It actually activates the fibre molecules so that they can chemically attack the dye. As seen in table - 7, the colour strength values obtained for dyed viscose rayon fibre are higher than those obtained for dyed cotton. As the cross section of viscose rayon is serrated which enables them to absorb more dye as compared to cotton having kidney shaped cross section. Also, the degree of polymerization for cotton is >1000, and viscose is 300 - 400 and the dye ability of fibres and degree of polymerization are inversely proportional. Therefore, Viscose rayon (F - II) gives excellent results compared to cotton (F - I) when dyed using homo - bifunctional reactive dye. (Figure: 1).





Paper ID: SR241217105642 DOI: https://dx.doi.org/10.21275/SR241217105642

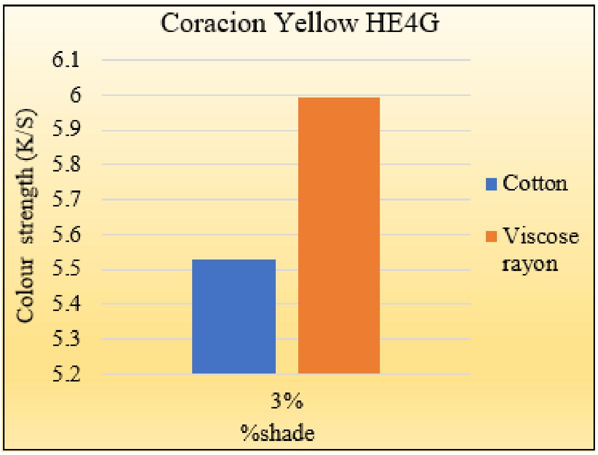


Figure 1: Comparison of colour strength (K/S) for cotton and viscose rayon dyed with homo - bifunctional dye

b) Evaluation of fastness properties: The prime important properties required for any dyeing with consumer point of view is the fastness properties. Therefore, to evaluate the most important dyeing parameter, the fastness properties of optimal dyed samples were determined. The three most commonly required fastness properties, i. e., washing, rubbing and light were evaluated and the results were obtained by using grey scale in terms of ratting (from 1 to 5). Rubbing fastness property is being evaluated as DRF (Dry Rubbing Fastness) and WRF (Wet Rubbing Fastness). As seen in table 8., both cellulosic fibres dyed with homo - bifunctional reactive dye shows good fastness to light and excellent fastness to washing and rubbing as reactive dye tend to form covalent bond with the fibre in presence of alkali increasing the dye uptake during fixation.

Table 8: Fastness ratings for dyed cotton and viscose rayon

Name of Dye	Name of Fibre	Fastness Ratings				
		Washing Fastness (1 to 5)		Dry Rubbing Fastness (DRF) (1 to 5) (Colour stain)	Wet Rubbing Fastness (WRF) (1 to 5) (Colour stain)	Light Fastness (1 to 8) (Colour fading)
		Colour change	Colour stain			
Coracion Red HE3B	Cotton	5	5	5	5	4
	Viscose	5	5	5	5	6
Coracion Navy Blue HE2R	Cotton	5	5	5	5	4
	Viscose	5	5	5	5	6
Coracion Yellow HE4G	Cotton	5	5	5	5	4
	Viscose	5	5	5	5	6

5. Conclusion

The present research focuses on the comparative study of dyeing cotton and viscose rayon fabric using homo - bifunctional reactive dye by exhaust method. When these dyed fabrics were analysed for their colour strength, it was seen that viscose rayon showed better exhaustion property as compared to cotton as it has lower degree of polymerisation and dyeability is inversely proportional to degree of polymerisation. Also when washing, rubbing and light fastness were evaluated for all the dyed samples, the results showed that for both cotton and viscose rayon fastness to washing, rubbing and light are good to excellent. This is because homo - bifunctional reactive dye forms a covalent bond with cellulosic fibres under alkaline pH conditions.

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