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Optimization of Enzymatic Treatment and Reactive Dyeing of Viscose Fabric in One-bath Process

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Abstract

Conventional pretreatment and dyeing processes of viscose fabric are mainly conducted in two baths with substantial amounts of water and auxiliaries. These processes comprise one bath of two–stages for enzymatic de-sizing and alkaline treatment adopted using sodium carbonate with peroxide bleaching formulations and a second bath for the dyeing process. In this study, a regular viscose woven fabric was initially pretreated with a commercial desizing enzyme and subsequently dyed with different reactive dyes in the same exhaust bath process. The effect of one-bath enzymatic pretreatment and reactive dyeing was investigated and optimized, employing enzyme and mono- and/or bifunctional reactive dyes at various concentrations. The results showed that the one-bath pretreatment and dyeing process could be performed successfully, exhibiting remarkable colour strength and excellent performance equal to that with the conventional pretreatment and dyeing method. Both the pretreated fabrics via the bio-method and the conventional one exhibited approximately equal efficiency in terms of improved dyeing and fastness properties. The bifunctional reactive dyes, RR 195 and RBl 5, exhibited higher degrees of dye exhaustion and total fixation yield than those of the monofunctional reactive dyes, RR 180 and RR 31. Although the shorter the one-bath enzymatic pretreatment and dyeing process, all the reactive dyeings using this Bio-method showed comparable CIE L*b*a* and colour difference values ΔE to the conventionally dyed sample using Conv-method, particularly in the case of bifunctional dyes.

Keywords: Viscose Fabric; Enzyme; Pretreatment; Reactive Dyes; Dyeing.

1. Introduction

Viscose is one of the most commonly regenerated fibers applied to several species of clothing and textile materials [1-6]. The performance evaluation of viscose has been reported in terms of its reducing fiber surface fibrils and pilling formation parameters [7-10]. It has been found that the chemical and enzymatic pretreatments can restrict this problem, which may result in improving the wetting properties and keep the fabric strength at satisfactory levels. On the other hand, viscose fabrics are commonly dyed with reactive dyes, which are very popular because of their brilliance, wide range of hues, and excellent colourfastness properties. Attempts to maximize the reactive dye uptake and fixation yield to viscose via its chemical bonding have included the application of bifunctional reactive dyes. These dyes can react more readily with viscose, showing better dye exhaustion and fixation than the monofunctional types, resulting in improved dye fixation yields. One of the most important dyeing methods of viscose fibers is the conventional exhaust method. However, the large water consumption makes this process particularly not attractive on ecological grounds. In order to achieve effective production process, the fabric requires separately pretreatment bath to render the fabric has satisfactory levels of wetability, swelling and reduction of fibrillation tendency, which in turn, lead to a better dye uptake and increase the forces of dye-fiber interactions [11-16]. Moreover, several attempts have been made to shorten the conventional exhaust two-bath processes of pretreatment and dyeing viscose into one-bath process. In this context,

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there is a growing interest in the issues of textile productivity and process optimization using innovative, eco-friendly, and sustainable dyeing methods to reduce the amount of water, energy consumption and hazardous coloured effluent discharge [17-19]. Recently, the application of one-bath pre-treatment and dyeing of viscose fabric with enzyme in the cold pad-batch method has been greatly save the chemicals and energy, and reduce the environmental pollution with an optimized production process [20]. An alternative method of viscose fabric pre-treatment and dyeing by the exhaustion technique in one bath is also of growing interest. But there is still a lack of research work on the combined exhaust process of raw viscose like cotton fabrics. Several attempts have been reported on the pre-treatment and dyeing cotton in a single bath and stages of conventional and bio-treatment of raw cotton using enzymes studied and also dyeing carried out in the same bath [21-23]. Also, a new process of combined pretreatment and reactive dyeing of cotton in a single bath was investigated and the process completed almost in half of the conventional dyeing time [24]. As a part of our ongoing interest to challenge the conventional dyeing process of reactive dyes, the present work optimizes the process of enzymatic pre-treatment of raw viscose fabric with subsequent dyeing in the same bath using different reactive dyes. The results were compared with those obtained by the conventional process in separate baths.

2. Experimental

2.1. Materials and Chemicals

A plain-weave viscose gray fabric, 115g/m2, 360 ends/10cm and 280 weft yarns/10cm, was supplied by Modern Kobbafor Weaving & Finishing Co (El-Obour City, Egypt). Seven commercial reactive dyes, comprising two hetero-bifunctional monochloro-s-triazine/vinylsulphone (MCT/VS) dyes, (RR 195, RB 222), two homo-bifunctional Bis(MCT) dyes (RO 84,RR 141), one homo-bifunctional Bis(VS) dye (RBl5) and two monofunctional dyes of MCT and VS dye types (RR 31, RR 180, respectively). These dyes were supplied by DyStar and Oh Young Industrial Co. Ltd., and used as received. The C.I. generic name and chemical structures of these dyes are illustrated in Table1.Soda ash (Sodium carbonate anhydrous), Glauber's salt (sodium sulphate anhydrous) and glacial acetic acid were supplied by El-Nasr Pharmaceutical Chemicals Company, Egypt. The efficient enzyme (α-amylase) namely, Bactosol®HPA Liq. was obtained from Archroma, Egypt. Wetting agent (GB Detergent SRM Conc.) and Ludigol (mild oxidizing agent that helps to prevent dyes from reduction) were purchased from GB Chemical Products Co., Egypt. Other auxiliaries of sequestering agent (Wat SEQ-10) and an alkylphenol ethoxylate (APEO) free non-ionic detergent (Wat 870) were supplied by WATCO Dyestuffs & Textile Auxiliaries, Egypt. An anionic leveling agent (Moral 45), supplied by Istanbul Chem., Egypt, was also used through this work.

2.2. Conventional Pre-treatment and Dyeing Processes (Conv-method)

The conventional pre-treatment and dyeing processes of viscose fabric were conducted as shown in Figure 1, and the total process time was approximately 360 min. The fixation dyeing temperature was carried out at 80 °C for **RR 141, RR 31, RO 84 and 60°C for RR 195, RR 180, RBl 5 and RB 222**.

Pre-treatment (One bath-Two stages -Total Time 190 min)

1. Deszing (2g/l Bactosol®HPA Liq., 2g/l Wat 870, 1g/l Wat 50) – 60 min
2. Bleaching (2g/l H2O2 50%, 1g/l Stabilizer, 1g/l Wat 50, 2g/l Soda Ash) – 70 min
3. Hot Rinsing/Neutralization (1g/l Acetic acid) - 60 min

Dyeing stage (One bath/One stage- Total time 170 min)

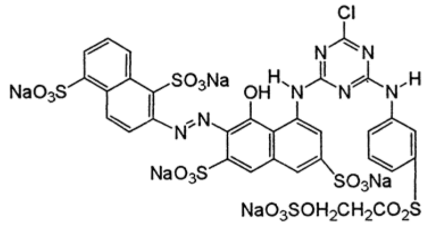
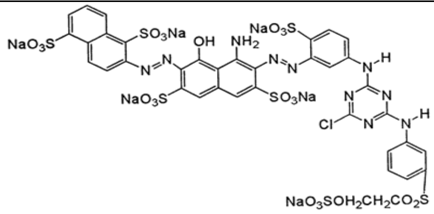
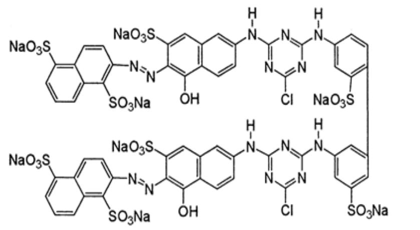
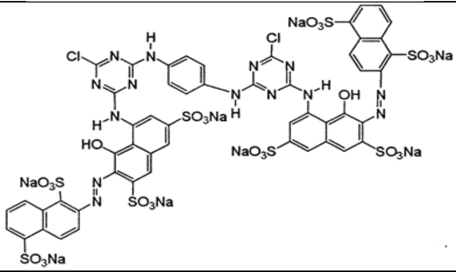
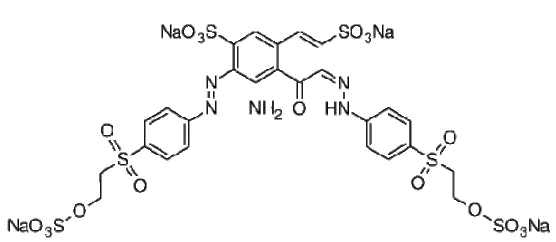
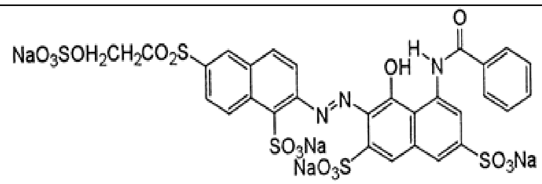
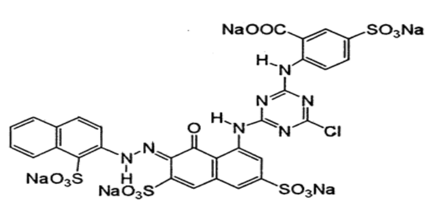
4. (1 g/l Moral 45, 20-40 g/l Gluber's Salt)
5. Reactive Dye (1-3 % owf),
6. 15-20 g/l Soda Ash
7. Cold Neutralization Acetic acid) /Hot and Cold Rinsing

2.3. One-bath Pre-treatment and Dyeing method (Bio-method)

The temperature/time graph of the visibility for one-bath pre-treatment and dyeing process by using various concentrations of Bactosol®HPA Liq. enzyme (1-4 g/l) and 1-4g/l of each Wat 870 and detergent SRM in addition to 2 g/l Ludigol for all reactive dyes studied, as shown in Figure 2, with total time of approx. 175 min. The fixation stages of all reactive dyes were carried out at the same dyeing temperatures mentioned in the Conv-method.

The conventionally and enzymatically pre-treated fabrics dyeing with dye concentrations (1-3% owf) and the amounts of Na_2SO_4 and Na_2CO_3 used for all the reactive dyes was carried out in accordance to the recipes listed in Table 2.

Table 1: Commercial names and chemical structures of the reactive dyes

CI Generic name	Commercial name	Dye structure	Dye Class M. Wt.
CI Reactive Red 195 (RR195)	**Remazol Red H6BN (DyStar)**		**MCT/VS 1136**
CI Reactive Blue 222 (RB222)	**Sunfix Navy Blue SB (Oh Young)**		**MCT/VS 1357**
CI Reactive Orange 84 (RO84)	**Suncion Orange HER (Oh Young)**		**Bis(MCT) 1850**
CI Reactive Red 141 (RR141)	**Suncion Red HE7B (Oh Young)**		**Bis(MCT) 1774**
CI Reactive Black 5 (RBl5)	**Remazol Black B (DyStar)**		**Bis(VS) 991**
CI Reactive Red 180 (RR180)	**Sunfix Red F3B (Oh Young)**		**VS 934**
CI Reactive Red 31 (RR31)	**Procion Brilliant Red H8B (DyStar)**		**MCT 992**

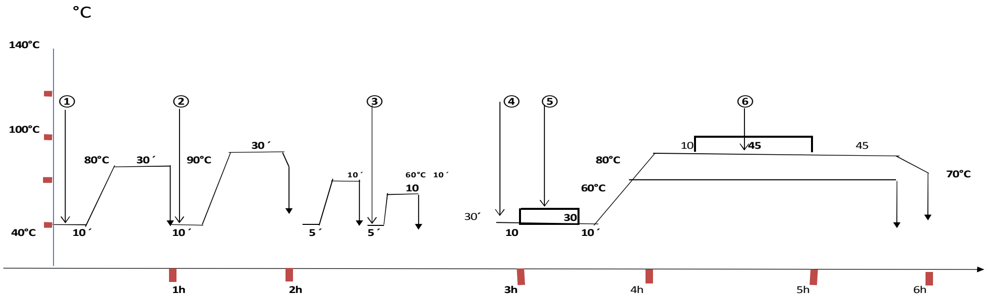


Figure 1 Temperature/time graph of the conventional two-bath process (**Conv-method**)

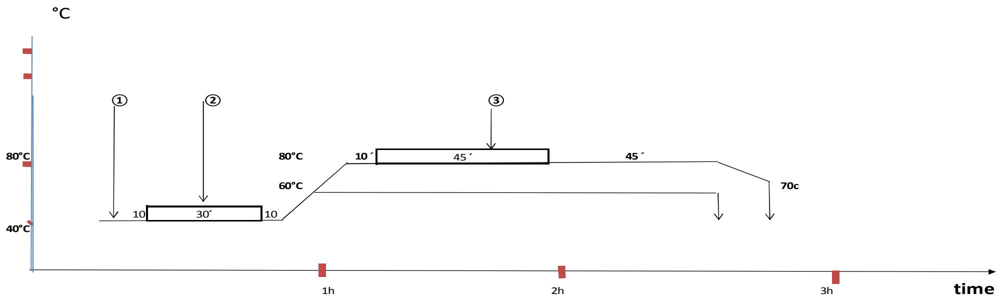


Figure 2 Temperature/time graph of the one-bath process (**Bio-method**)

① Auxiliaries (2g/l Bactosol®HPA Liq., 1g/l Wat 870,1g/l SRM, 1g/l Wat 50, 1g/l Moral 45,2g/l Ludigol, 20-40 g/l Glauber's Salt) – 10 min

② Reactive Dye (1-3 % owf), 30 min ③ Soda Ash (15-20 g/l) ④Cold Neutralization Acetic acid) /Hot and Cold Rinsing

Table 2: Amounts of the Glauber's salt and soda ash of the Bio- and Conv-methodsreactive dyeing bath with 10:1 liquor

Dye Conc. (%owf)	Na_2SO_4 g/l	Na_2CO_3 g/l
1	20	15
2	30	20
3	40	20

2.4. Measurements and Analyses

2.4.1. Dye exhaustion

The reactive dye uptake by viscose fabric was measured by sampling the dyebath before and after the dyeing method. The dyebath concentration (g/l) was measured at λmax of each dye on Shimadzu UV-2401PC UV/Vis spectrophotometer. The percentage of the dye exhaustion on viscose (%E) was calculated using Eqn. 1:

$$\%E = \left(1 - \frac{C2}{C1}\right) \times 100 \qquad (1)$$

Where, C_1 and C_2 are the concentrations of dye in the dyebath before and after dyeing, respectively.

Dye fixation and Colour yield

The dye fixation ratio (%F), the percentage of the exhausted dye chemically bound on the fabric was measured by soaping the dyed viscose samples in a bath containing 2 g/l nonionic detergent and 2 g/l sodium carbonate at a liquor ratio 20: 1 and at 95°C for 15 min to remove the unfixed dye. This procedure was repeated until the soaping solution was clear. The colour yield (K/S) of the dyed samples was determined using UltraScan PRO spectrophotometer with a D65 illuminant and 10° standard observer at the maximum wavelength of each dye in accordance with the Kubelka–Munk equation (Eqn. 2). The data collected from the samples dyed by the two dyeing processes and the deviation values of the colour strength (ΔK/S) were calculated using Eqn. 3, where lower percentages indicate lower colour strength of the samples dyed by Bio-method compared with the samples dyed by the Conv- method and vice versa.

$$K/S = \frac{(1-R)^2}{2R} \qquad (2)$$

Where, R is the decimal fraction of reflectance of the dyed fabric; K is the absorption coefficient; and S is the scattering coefficient.

$$\Delta K/S = \frac{(K/S)_{Bio.}}{(K/S)_{Conv.}} \times 100 \quad (3)$$

Also, the percentage dye fixation ratio (%F) on viscose was calculated using Eqn. 4:

Where, $(K/S)_{Bio.}$ and $(K/S)_{Conv.}$ are the colour yield of the dyed fabrics using Bio- and Conv-methods, respectively.

$$\%F = \frac{(K/S)_2}{(K/S)_1} \times 100 \qquad (4)$$

Where, (K/S)is the colour yield of the dyed fabrics with the values before soaping (1) and after soaping (2).

The colourreadings of all dyed fabrics were also expressed in the CIELAB colour space system (often denoted as L*, a*,b* coordinates). In which, L* represents lightness or darkness of the sample (a higher lightness value represents a lower colour yield); a* denotes redness if positive value or greenness if negative; and b* represents yellowness if positive or blueness if negative.

2.4.2.COD Measurement

Laboratory analysis of the chemical oxygen demand COD of the residual dyebath was carried out in accordance with Standard Methods for Examination of Water and Wastewater [25].

2.4.3.Fastness testing

The dyed viscose fabrics, after washing-off using 2 g/l nonionic detergent at 80°C for 15 min, were tested in accordance with ISO standard methods [26-28]. The wash fastness test was assessed in accordance with the standard method ISO 105-C06 B2S [26] (4g/l of ECE detergent, 1 g/1 of sodium perborate, 25 steel balls) at 50 °C for 30 min and at a liquor ratio of 50:1. Fastness to acidic and alkaline perspiration was determined with a perspirometer set at specific pressure, temperature and time in accordance with ISO 105-E04 [27]. Any change in colour of the dyed specimens (Alt) and colour staining of the adjacent cotton (SC) and wool (SW) multi-fibers was then assessed with the corresponding ISO grey scales for colour change and staining. Light fastness was also assessed using a Xenon arc lamp test in accordance with ISO 105-B02 [28].

3. Results and Discussion

3.1. Effect of enzyme concentration

The raw viscose fabric was treated using the Bio-method at various enzyme concentrations (1-4 g/l). The effect of this treatment on the dye ability of the viscose fabric samples was examined using different reactive dye types (**RR 31**, **RR 180**, **RR 195**, **RO 84**, **RBl 5**). From the results given in Table 3, it is seen that the one-bath pretreatment and dyeing of the gray fabric is very encouraging using Bio-method. Within the chosen concentrations of enzyme, the maximum dye uptake was achieved at 2-3 g/l and there was no reduction in the dye uptake in all cases of reactive dyes used. From which, the types of bifunctional dyes exhibited approximately similar results of dye exhaustion and total fixation yield values to the conventionally processed fabric using the Conv-method. However, the monofunctional dyes showed relatively lower values, particularly at low enzyme dosages. In other words, the dye build up was found to be more efficient with hetero-bifunctional reactive dyes, **RR 195**, followed by the homo-bifunctional bis(VS) dye **RBl 5,** while the monofunctional dyes **RR 31** and **RR 180** showed a relatively lower values dye exhaustion (%E) and total fixation yield (%T), as shown in Figures 3-6. Also, the Bis(MCT) dyes **RO 84** exhibited the lowest dye exhaustion (%E) and total fixation yield (%T), which may be attributed to its high molecular weight. These findings could also be associated with the higher efficient of the bifunctional dye **RR 195**, imparting much more chance for fixation on viscose fabric through the chemical reaction between the dye MCT/VS reactive system and the fiber hydroxyl groups. Moreover, in the course of the pre-treatment stage, the use of enzyme in the presence of wetting agent could facilitate starch decomposition and help the removal of the short fibers, fuzz and spinning oil, so that it can improve the fabric softness and accelerate water absorption, promoting higher diffusion of dye molecules into the fiber during the dyeing stage. The combination of pre-treatment and dyeing using one-bath Bio-method has a relatively high dye exhaustion and total dye fixation if compared to the Conv-method, following the order **RR 195** >**RBl 5**>**RR 180**>**RR 31** > **RO 84**. The difference in colour strength (ΔK/S) of the Bio-method compared to the Conv-method showed a reasonable colour yield on the viscose fabric, which was approximately similar as shown in Table 4.

3.2. Effect of dye concentration

To further evaluate the one-bath pre-treatment and dyeing method, dyeing of viscose fabrics were conducted at different dye concentrations 1-3% owf. The colour strength (K/S), for both Bio- and Conv-methods were examined. From the results, mentioned in Figure 7, it can be seen that the K/S values of the Bio-method dyed viscose samples increased with increasing the dye concentration and secured relatively higher dye uptake than those of the Conv-method with satisfactory results of CIE L*a*b* and ΔE, which showed acceptable colour difference values of approximately ΔE < 1.5 particularly in case of **RR 195** if compared to the values of **RR 180** (ΔE >2), as given in Table 5.

Table 3: Colour strength data of the dyed viscose fabric using Bio- and Conv methods at different enzyme concentrations

Enzyme Conc. (g/l)	RR31		RR180		RO84		RBl5		RR195	
	K/S	ΔK/S	K/S	ΔK/S	K/S	ΔK/S	K/S	ΔK/S	K/S	ΔK/S
Conv.	**21.1**	**100**	**14.92**	**100**	**17.01**	**100**	**29.96**	**100**	**15.97**	**100**
1	21.73	103	16.98	113	17.08	100	31.67	106	18.53	116
2	21.77	103	16.43	110	17.37	97	33.39	111	17.81	111
3	21.16	100	15.98	107	16.79	99	31.43	105	17.80	111
4	21.14	100	15.71	105	16.70	98	30.86	103	17.78	111

Table 4: Effect of enzyme concentrations (1-4 g/l) on the colour CIE L*a*b* and colour difference (ΔE) of the dyed viscose fabric using Bio-method for **RR180** and **RR195** compared to the Conv-method

Enzyme Conc. (g/l)	K/S	L*	a*	b*	C*	*h*	ΔE
RR195							
Conv.	15.97	40.83	56.69	-5.51	56.96	354.44	--
1	18.53	40.13	59.12	-3.37	59.22	356.73	3.31
2	17.81	40.76	59	-3.91	59.13	356.21	2.81
3	17.8	41.51	58.39	-4.41	58.55	355.68	2.14
4	17.78	40.77	58.42	-4.27	58.57	355.82	2.13
RR180							
Conv.	14.92	41.82	58.85	-4.06	58.99	356.06	--
1	16.98	40.75	58.75	-3.49	58.85	356.6	2.06
2	16.43	40.94	58.68	-4	58.82	356.1	2.06
3	15.98	40.82	58.42	-3.81	58.54	356.27	1.77
4	15.71	41.33	58.32	-4.32	58.48	355.77	1.87

Where, L* represents lightness or darkness of the dyed sample, a* denotes the red/green value, b* the yellow/blue value, C* specifies chroma or saturation of the colour and h° denotes hue angle

Table 5: Effect of dye concentrations (1-3 % owf) on the colour data of the dyed viscose fabric using Bio- and Conv-methods

Dye Conc. (% owf)	Dyeing Method	K/S	L*	a*	b*	C*	h	ΔE
RR195								
1	Conv.	7.39	47.24	55.12	-7.95	55.69	351.79	--
	Bio	8.17	47.39	56.41	-8.18	57	351.75	1.31
2	Conv.	15.97	40.58	58.69	-3.82	58.82	356.27	--
	Bio	17.81	40.19	59.53	-2.49	60.58	357.65	1.62
3	Conv.	24.91	36.73	58.72	0.24	58.72	0.24	--
	Bio	28.4	37.41	59.64	0.89	59.65	0.86	1.32
RR180								
1	Conv.	6.85	48.79	54.35	-8.29	54.98	351.33	--
	Bio	8.43	46.99	55.83	-7.52	56.34	352.33	2.45
2	Conv.	14.92	41.82	58.85	-4.06	58.99	356.06	--
	Bio	16.43	40.94	58.68	-4	58.82	356.1	2.06
3	Conv.	23.07	38.34	59.09	-0.88	59.09	359.15	--
	Bio	29.96	36.31	59.68	2.57	59.73	2.47	4.05

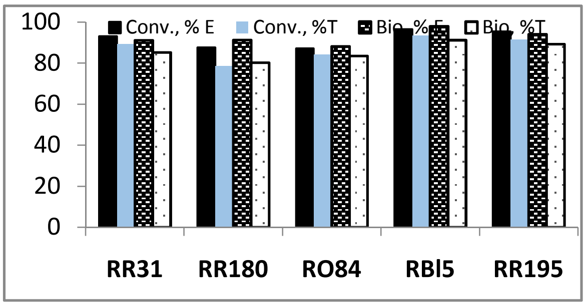


Figure 3 The reactive dye exhaustion (%E) and total dye fixation (%T) using Bio-method dyeing at 1 g/l Enzyme concentration compared to the Conv-method

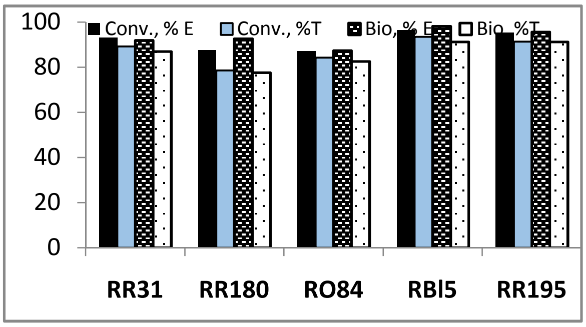


Figure 4 The reactive dye exhaustion (%E) and total dye fixation (%T) using Bio-method dyeing at 2 g/l Enzyme concentration compared to the Conv-method

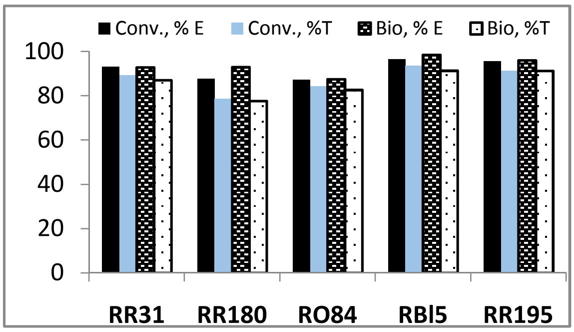


Figure 5 The reactive dye exhaustion (%E) and total dye fixation (%T) using Bio-method dyeing at 3 g/l Enzyme concentration compared to the Conv-method

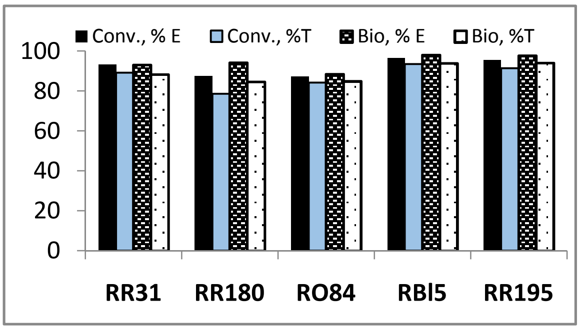


Figure 6 The reactive dye exhaustion (%E) and total dye fixation (%T) using Bio-method dyeing at 4 g/l Enzyme concentration compared to the Conv-method

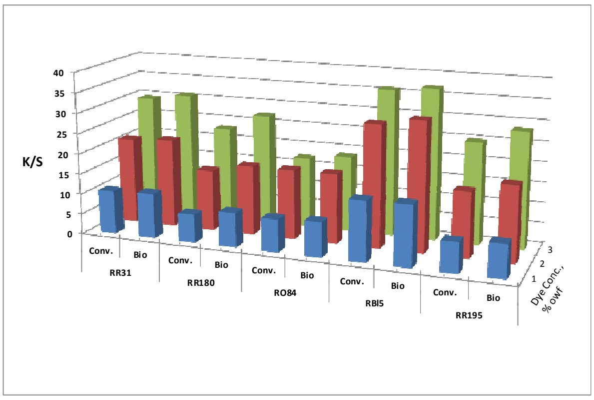


Figure 7 Effect of dye concentrations (1-3 %owf) on the colour strength data of the dyed viscose fabric using Bio- and Conv methods

3.3. Effect of wetting agent concentration

To further investigate the effect of wetting agent on the reactive dyeing performance using one-bath Bio-Method, the fabrics were treated with different concentrations of wetting agent (1-4 g/l) at a constant concentration of enzyme (2 g/l), followed by dyeing with 2% owf dye concentration for RR 195 and RR 180. The effect of wetting agent on the colour yield K/S and the dye exhaustion were secured in Table 6 and Figure 8. From which, It can be obviously seen that the colour strength and dye exhaustion values increased with increasing the concentration of wetting agent within the range of 1-4 g/l.

Adding the wetting agent in the pre-treatment stage could improve the hydrophilicity of the fiber for further dye affinity of the dye molecules at the dyeing stage to diffuse into the fiber, so that the dyes are more easily combined with fibers, which, in turn, increases the dye exhaustion and K/S values of the dyed samples. From the CIE L*a*b* and ΔE data, mentioned in Table 6, it was noticed that the increase of wetting agent concentration from 2 to 4 g/l showed insignificant effect on the colour difference values of both RR 195 and RR 180 dyes, which ensure the suitability of the Bio-method dyeing, even at low wetting levels.

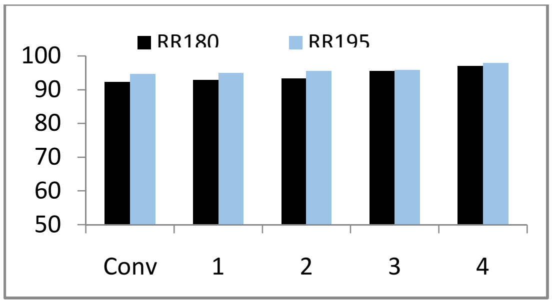


Figure 8 The reactive dye exhaustion (%E) using Bio-method dyeing at different wetting concentrations compared to the Conv-method for **RR 180** and **RR 195**

3.4. COD measurements

The COD values of the dyeing effluents of both Conv- and Bio-Methods were further studied to evaluate the environmental impact of the two processes. The results of both Bio-and Conv-Methods with three different types of reactive dyes (RR 180, RBl 5 and RR195) are shown in Figure 9. The enzymatic one-bath pretreatment and dyeing process caused a significant reduction in the COD of the reactive dyeing effluent of 2% owf dyeings, which in turn, impart much better impact to the environment as expected. This observation is clearly obvious in the case of the heter-bifunctional RR 195, as its dyeing effluent of the Bio-Methodsecured91 reduction in COD value. It is also clear that the dyeing effluent of the monofunctional RR 180 with Bio-Method gave almost comparable result to the heter-bifunctional RR 195. Since, Ludigol acts as a mild oxidizing agent, it is anticipated that its compounding in the dye effluent can convert the desized products, produced by the enzymatic treatment of raw viscose fabric, into gluconic acid, lowering the environmental load.

Table 6 The colour data of the one-bath Bio-method dyed samples at different wetting concentrations (1-4 g/l) compared with conventionally dyed samples

Wetting Conc. (g/l)	K/S	L*	a*	b*	C*	*h*	ΔE
RR195							
Conv.	15.97	40.58	58.69	-3.82	58.82	356.27	--
1	14.49	43.04	60.44	-4.76	60.63	355.49	1.51
2	17.81	39.97	60.92	-1.54	60.58	357.65	1.29
3	18.6	40.12	60.13	-3.21	60.82	356.98	1.63
4	19.48	40.19	59.53	-2.49	60.94	358.55	1.62
RR180							
Conv.	14.92	41.82	58.85	-4.06	58.99	356.06	--
1	15.3	41.06	59.85	-3.52	59.53	356.61	1.7
2	16.43	40.94	58.68	-4	58.82	356.1	2.06
3	17.65	40.52	59.99	-2.76	60.06	357.37	2.01
4	18.5	40.18	59.91	-2.21	59.95	357.89	2.44

Table 7: Fastness Properties of the dyed viscose samples using Conv- and Bio-methods at 2% owf reactive dye concentration

Dye	Dyeing Method	K/S	Washing fastness*			Perspiration fastness*						light
						Acidic			Alkaline			
			CC	SC	SW	Alt	SC	SW	Alt	SC	SW	
RR195	Conv.	15.97	4	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4
	Bio	17.81	4	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4
RB222	Conv.	19.07	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4	4-5	4
	Bio	19.72	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4	4-5	4
RO84	Conv.	17.01	4	4-5	4-5	3-4	3-4	3-4	4	3-4	3-4	3-4
	Bio	17.37	4	4-5	4-5	3-4	3-4	3-4	4	3-4	3-4	3-4
RR141	Conv.	17.68	4-5	4-5	4-5	3	3-4	4-5	4	4-5	3-4	4-5
	Bio	18.64	4-5	4-5	4-5	3	3-4	4-5	4	4-5	3-4	4-5
RBl5	Conv.	29.96	4-5	5	4-5	4-5	4-5	4-5	4-5	4-5	5	4
	Bio	33.39	4-5	5	4-5	4-5	4-5	4-5	4-5	4-5	5	4
RR180	Conv.	14.92	4-5	5	4-5	4-5	4-5	4	4-5	4-5	4-5	4
	Bio	16.43	4-5	5	4-5	4-5	4-5	4	4-5	4-5	4-5	4
RR31	Conv.	21.1	4	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	Bio	21.77	4	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5

* CC = Change of colour SC = Staining on cotton SW = Staining on wool

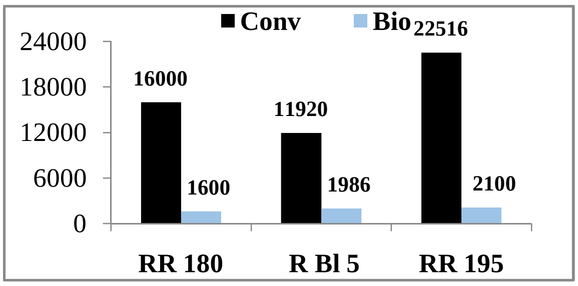


Figure 9 COD values of the dyeing effluents of both Conv- and Bio-methods with 2% owf dyeing of **RR180**, **RBl 5** and **RR 19**

4. Conclusion

The one-bath pretreatment and dyeing of raw viscose fabric using Bio-Method compared to the conventionally two-bath process was studied. The optimal one-bath process conditions of Bio-method were evaluated by the determination of colour strength of the dyed samples and dyeing parameters of exhaustion percentages, total dye fixation for each of the reactive dyes used. The Bio-method dye build up was found to be more efficient with hetero-bifunctional reactive dyes, RR 195, followed by the homo-bifunctional bis(VS) dye RBl 5 while the monofunctional dyes RR 31 and RR 180 have a relatively lower values dye exhaustion (%E) and total fixation yield (%T) and the Bis(MCT) dyes RO 84 exhibited the lowest dye exhaustion (%E) and total fixation yield (%T). The enzymatic one-bath pretreatment and dyeing process caused a significant reduction in the COD of the reactive dyeing effluent of 2% owf dyeings as in the case of both bifunctional dyes RR 195 and RBl 5 and monofunctional dye RR 180, which in turn impart much better impact to the environment as expected. Also, there was almost same fastness properties of the dyed samples by one-bath Bio-method and gave the same effect to those obtained by the two-bath Conv-method. This observation can motivate the application of Bio-method for further demanding of dyeing viscose with reactive dyes at reduced time, water and energy parameters.

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