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Dyeing Properties of Bamboo/Cotton Blended Yarns By Single-Bath Combined Process

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Nowadays the bioprocesses of cellulosic materials using various enzymes have almost become a common application, since they have many advantages over the conventional processes. These treatments undergo in mild and environmentally friendly conditions, compared to the conventionally carried out processes. Pectinase is used for scouring and catalase for removing the residual H_2O_2 in the bleach baths and on the fabric before the dyeing stage. In this work, C.I. Reactive Red 21 and C.I. Reactive Blue 19 were used to dye untreated bamboo/cotton blended yarns by a single-bath combined process, in which various enzymes, namely, pectinase and catalase were employed. This process is completed almost in half of the conventional dyeing time and all of the stages, namely, scouring, bleaching and dyeing, were carried out in a single bath without replenishing of the process water until the end of the dyeing. In the single bath combined process, the untreated yarn was first scoured by pectinase and the yarn was then bleached by H_2O_2 in the same bath and after the hydrogen peroxide bleaching, the catalase enzyme was added to the bath to remove H_2O_2 residues before reactive dyeing. Without carrying out any intermediate washings/rinsing between these processes, the reactive dyeing was carried out by a conventional way in the same bath and finally the yarn was taken from the bath and washed to remove the unfixed dyes. The colour yield, dyeing fastnesses, dyeing repeatability and tensile strengths of the dyed materials were compared with those of the dyeing which were carried out conventionally in separate baths. The single bath combined process has many benefits in terms of water savings, reducing process times and energy consumptions, compared to the conventional preparatory and dyeing processes of bamboo/cotton-blended yarns.

Key Words: Enzymes, Combined-dyeing, Cellulosic and its blends dyeing, Bamboo.

INTRODUCTION

The preparatory processes of cellulosic materials by the use of enzymes have generated a great deal of interest in the light of cost savings, shortening the process times and reducing the chemical damage to the fibre and the growing environmental concerns. The possibilities of enzymatic processes in detail were discussed and suggested to use various types of enzymes, namely amylase, protease, lipase, pectinase, laccase, glucose oxidase, catalase and cellulase, from the beginning to the end of the finishing processes of textile substrates[1]. Several books on how to process textile materials with different enzymes are also available[2,3]. The use of amylases for desizing of starch-sized cotton fabrics is a very common technique today and the control of pH, enzyme concentration, temperature and electrolyte are essential for effective desizing[4,5]. The bio-preparation of cotton fabrics were studied and the efficiency of different types of pectinases and a single step scouring/bleaching with enzyme-generated peroxide were investigated[6]. Also an other research on cotton scouring with various enzymes, namely pectinase, lipase, protease and cellulase and compared the results with those of obtained with the alkaline scouring process[7]. The pectinase-scoured cotton fabric showed the same whiteness as the caustic-soda scoured fabric.

Bamboo, as a regenerated cellulosic fibre, is being more widely used in the textile industry due to its features such as being easy dye ability, absorbency, soft feeling, breathability, antibacterial activity, having a smooth texture and environmentally friendly. It's the only 100 % biodegradable textile material, which is naturally recycling itself.

Bamboo fibres and its blends have wide prospects in the field of medical suppliers and hygiene products, such as household wipes, sanitary napkin, wet wipe, baby diper, medical bandage, base cloth, inside lining, disposable sheet, nonwoven textiles and nanotechnology products. A few research works on the dyeing properties of bamboo fibre and its blends[8,9].

Dyeing of 100 % cotton knits was attempted with reactive dyes in catalase-treated hydrogen peroxide bleaching baths with intermediate washings and rinsing[10]. 100 % woven cotton fabric was used and studied the reactive dyeing in catalase-treated bleaching baths and the effects of residual hydrogen peroxide concentration on the colour yield[11-13]. Bio-preparation and conventional scouring processes of cotton fabrics were carried out and studied the bleachability and dyeing with reactive dyes of such pre-treated fabrics[14]. Different cellulase enzymes were used for the bio-preparation of raw cotton and carried out the reactive dyeings in the same bath[15]. Untreated, starch-sized 100 % woven cotton fabric was dyed after carrying out various enzymatic processes prior to the dyeing stage in the same bath. All the processes were carried out in a single bath without any intermediate washings/rinsing until the end of the reactive dyeing[16-18].

The aim of this work was to dye untreated 70 %/30 % bamboo/cotton yarn after carrying out various enzymatic processes prior to the dyeing stage in the same bath. All the processes were carried out in a single bath without any intermediate washings/rinsing until the end of the reactive dyeing. The results of the colour yield, dyeing fastnesses, dyeing repeatability and tensile strenght of the dyed materials with the conventional and single bath combined processes were compared.

EXPERIMENTAL

Throughout this experimental work, untreated 70 %/30 % bamboo/cotton yarns (Nm 34, S twill) were used.

Dyeing methods

Conventional process: The untreated yarn was scoured and bleached in separate baths in accordance with the conventional procedures as reported[5,19]. The yarn samples (10 g) were scoured with 1.5 % Rucolase PTZ (Rudolf-Duraner), at 55 ºC for 20 min, at pH 8.0-8.5 with a liquor ratio of 20:1. The scoured yarns were rinsed at 80 ºC for 10 min.

The scoured yarns were bleached with 0.2 mL/L wetting agent (Uniwett HGA), 11 mL/L H_2O_2 (35 %), 1 g/L NaOH, 2 g/L organic stabilizator (Prestogen P) at 80 ºC for 45 min. After the conventional bleaching process, the bleached yarn was washed at 70 °C for 20 min and neutralized, treated with 1 g/L washing agent at 95 °C for 10 min and this was followed by two rinses at 70 °C for 20 min and finally, a cold rinse was given for 10 min.

The preparatory processes were carried out conventionally in separate baths and the yarns were dyed by C.I. Reactive Red 21 (monoazo/vinylsulphonyl) and C.I. Reactive Blue 19 (anthraquinone). The 10 g samples were dyed. The amount of dye used was 2 % o.w.f. at liquor ratio of 20:1. The atmospheric dyeing was started at 60 °C and left for 1 h at that temperature. Eventually the bath was then cooled and dyed yarn was then rinsed six times, for 10 min at each stage, with a sequence of a warm rinsing at 70 °C, a second warm rinse at 70 °C and neutralizing with acetic acid, soaping at the boil, a third warm rinse at 70 °C, a final rinse at 50 °C and eventually, a cold rinse.

The processing time in conventionally prepared and dyed fabric is summarized in Table-1. When the untreated 70 %/ 30 % bamboo/cotton blended yarn was scoured, bleached and reactive dyed in separate baths, the total process time was 255 min.

TABLE-1
TOTAL PROCESSING TIME IN SCOURING, BLEACHING AND DYEING STAGES

Process	Process time (min)	Total rinsing time (min)	Total (min)
Scouring	20	10	30
Bleaching	45	60	105
Dyeing	60	60	120
		Total	255

Single-bath combined process: The process flow of the single-bath combined process was given in Table-2 and Fig. 1. During this process, no fresh water was added to the bath and all the applications were carried out in the same bath throughout. The dyed yarns were finally washed and rinsed as described earlier.

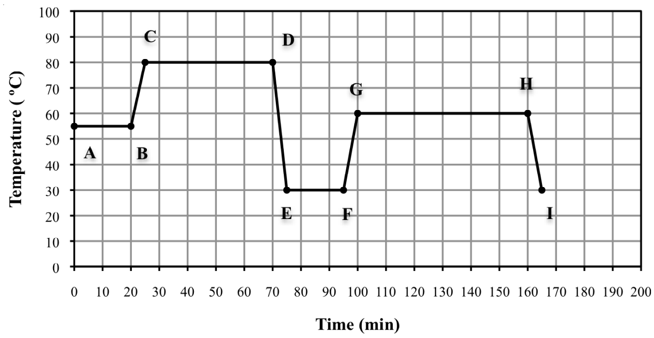
Each dyeing experiment was repeated four times with each dye. As shown in Fig. 1, total process time was 205 min, including the wetting, the heating and cooling stages. The pH and the temperature of the bath were precisely controlled during the process to keep the experimental variations at a minimal level.

Measurements and standards: Yarn samples dried at room temperature were tested for wettability using the AATCC Test Method 79-2007. The time between the water drop making contact with the yarn sample and its disappearance into the recorded as the wetting time.

The reflectance values were measured and the whiteness index of samples were determined on Datacolor Spectraflash SF600+ instrument with specular included mode and LAV (30 mm.) viewing aperture. The colour values of the yarns were calculated with D65 illuminant/10º observer values.

TABLE-2
SINGLE-BATH COMBINED PROCESS

	Concentration / Process Condition			
	Scouring	Bleaching	Anti-peroxide Process	Dyeing
Wetting agent (mL/L)	1	–	–	–
Pectinase enzyme (%)	1.5	–	–	–
Organic stabilizer (g/L)	–	2	–	–
NaOH (g/L)	–	1	–	–
H_2O_2 (35 %) (mL/L)	–	11	–	–
Catalase enzyme (g/L)	–	–	4	–
Na_2SO_4 (g/L)	–	–	–	80
Na_2CO_3 (g/L)	–	–	–	5
Dye (o.w.f. %)	–	–	–	2
Process temperature (ºC)	55	80	30	60
Process time (min)	20	45	20	60
Liquor ratio	20:1			



Stage	Application
A-B	Enzymatic scouring, set pH 8-8.5
C-D	Hydrogen peroxide bleaching
E-F	Anti-peroxide treatment by catalase addition
G-H	Dyeing
I	Washing/Rinsing stage

Fig. 1. Single-bath combined process

The Kubelka-Munk equation relates the absorption function of the substrate (K), the scattering function of the substrate (S) and the reflectance (R) in visible spectrum (400-700 nm) according to eqn. 1 given below.

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

The CIE Lab 1976 colour difference formula was used to express the colour differences (eqn. 2).

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \qquad (2)$$

ΔE^* is the CIELab colour difference between batch and standard. Here ΔL^*, Δa^*, Δb^* and hence ΔE^* are in commensurate units. ΔL^* denotes the difference between lightness (where $L^* = 100$) and darkness (where $L^* = 0$), Δa^* the difference between green (-a*) and red (+a*) and Δb^* the difference between yellow (+b*) and blue (-b*)[20].

The colour fastness to washing and rubbing tests were carried out in accordance with ISO 105-C06 (A1S test conditions; 40 ºC temperature, 0.5 h and 10 steel balls) and ISO 105-X12, respectively.

Tensile strength was determined by the strip method according to ISO 5081 standard, using Instron 4411. Yarns were conditioned for 24 h prior to testing under 20 ºC and 65 ± 2 RH % condition before the tests started. Five tests were carried out for every yarn tested. The tensile strength and strain values of samples were given Figs. 4 and 5.

RESULTS AND DISCUSSION

The wettability of bleaching yarns by single-bath combined process did not change but the whiteness index of the yarns is increased (Table-3). The K/S values of the dyed samples with C.I. Reactive Red 21 and Blue 19 are given in Figs. 2 and 3.

The single-bath combined process dyed yarns with C.I. Reactive Red 21 are slightly darker than the standard, but C.I. Reactive Blue 19 dyed yarns are more lighter. This needs a further investigation as far as the structure of the dyes, the enzyme/dye interactions and the process conditions are concerned.

TABLE-3
WETTABILITY AND CIE WHITENESS INDEX OF YARN SAMPLES

Yarn samples	Wettabilitiy (s)	CIE whiteness index
Untreated	8	18
Scoured	0.85	28
Bleached	0.35	58
Bleached by single-bath combined process	0.35	61

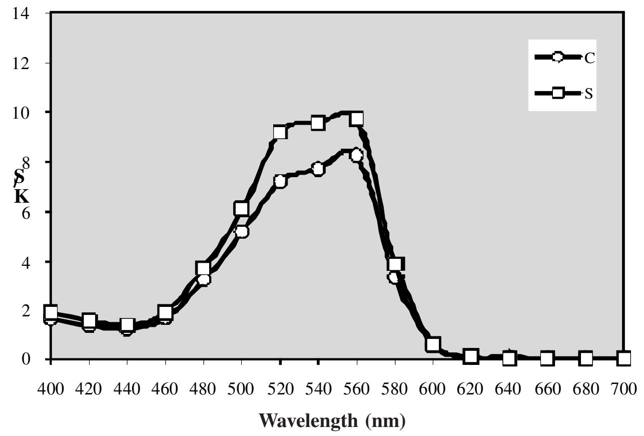


Fig. 2. Colour yield (K/S) of dyed yarns with C.I. Reactive Red 21 (C= Conventional process, S= Single-bath combined process)

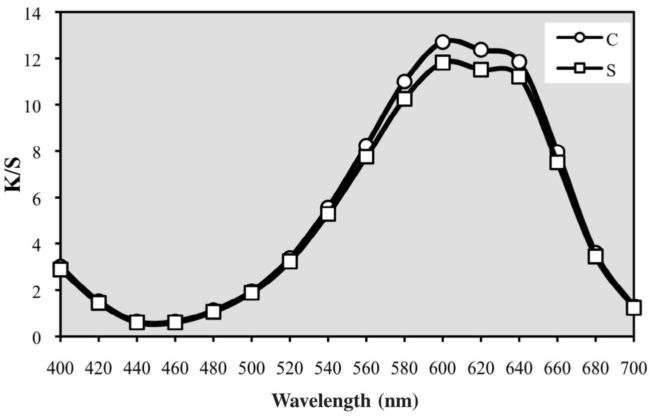


Fig. 3. Colour yield (K/S) of dyed yarns with C.I. Reactive Blue 19 (C= Conventional process, S= Single-bath combined process)

The CIE Lab values and colour differences of the dyed yarns are given in Table-4.

The colour fastness test results are summarized in Table-5. As shown in table, the wash and rubbing fastness results of the single-bath combined process dyed yarns are quite good. Using the single-bath combined process instead of conventional metod for dyeing bamboo/cotton blended yarns does not changed the colour fastness test results.

Figs. 4 and 5 show the mechanical change values of bamboo/cotton-blended yarns after the conventional and single-bath combined process.

Conclusion

With the data obtained in this experimental work, the following conclusions can be reached: The single-bath combined process is repeatable, as the precise control of the pH

TABLE-4
COLOUR VALUES AND COLOUR DIFFERENCES OF THE DYED FABRICS (*)

CIE Lab values	C.I. Reactive Red 21		C.I. Reactive Blue 19	
	Conventional process	Single-bath combined process	Conventional process	Single-bath combined process
L*	47.99	46.62	36.62	37.33
a*	58.00	59.11	2.75	2.80
b*	-5.91	-5.04	-42.68	-42.71
C*	58.30	59.33	42.77	42.81
h	354.19	355.13	273.68	273.74
X	28.21	27.01	9.19	9.56
Y	16.79	15.73	9.35	9.73
Z	21.05	19.36	31.87	32.77
ΔE*	1.97		0.71	

*The conventionally dyed fabrics were taken as standard.

TABLE-5
FASTNESS PROPERTIES OF DYED FABRICS

Dye	Method	Wash fastness[a]							Rubbing fastness	
		CC	SCA	SC	SN	SP	SA	SW	Dry	Wet
C.I. Reactive Red 21	C	5	5	4-5	4-5	5	4-5	4-5	5	4-5
	S	5	5	4-5	4-5	5	4-5	4-5	5	4-5
C.I. Reactive Blue 19	C	5	5	5	4-5	5	5	5	5	4-5
	S	5	5	5	4-5	5	5	5	5	4-5

[a]CC = Colour change; SCA = staining on secondary cellulose acetat; SC = staining on bleached unmercerized cotton; SN = staining on nylon 6.6; SP = staining on polyester (Terylene); SA = staining on acrylic (Courtelle); SW = staining on wool.

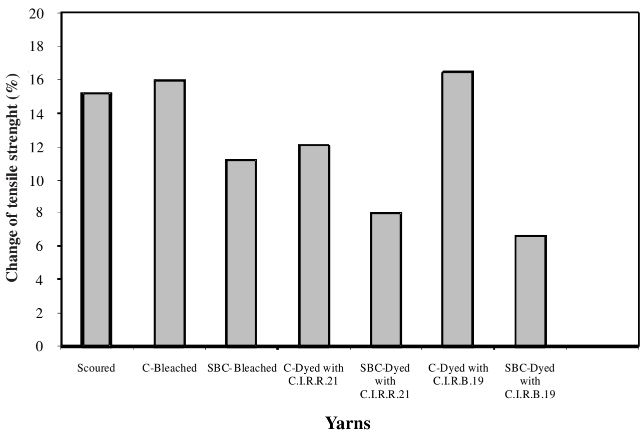


Fig. 4. Change of tensile strenght (%) values of bamboo/cotton blended yarns (C= Conventional process, SBC= Single-bath combined process), R.R.= Reactive Red, R.B.= Reactive Blue)

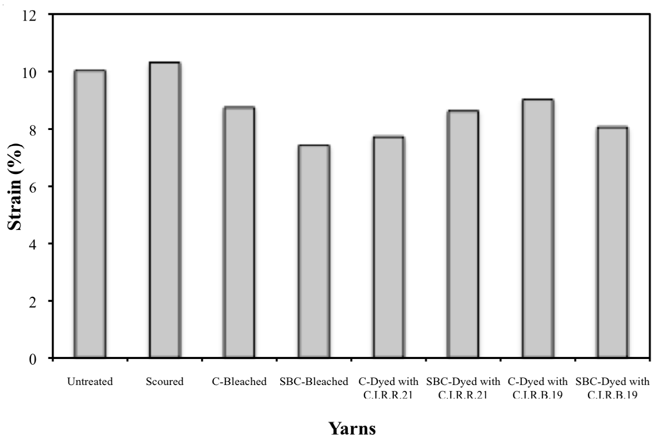


Fig. 5. Strain (%) values of bamboo/cotton blended yarns (C = Conventional process, SBC = Single-bath combined process, R.R. = Reactive Red, R.B. = Reactive Blue)

and the temperature of the dye bath is succeeded. The enzymes used in this experimental work showed compatibility with the auxiliaries in this work and as a result of this, level dyed yarns were obtained. The single-bath combined dyed yarns showed good washing, wet and dry rubbing fastness properties, compared with those of the conventionally dyed yarns.

The single-bath combined dyed yarns had better tensile strength values than the conventionally dyed yarns, because of the short process time and the mild conditions. In the single-bath combined process, the process time is very shortened than that of the conventional process. The single-bath combined process can be an advantage to dyeing for bamboo fiber and its blends at lower dyeing times (205 min) as an alternative process for conventional dyeing (255 min). This means more loadings at the industrial stage (> 20 %). The use of water in the single-bath combined process is almost 1/3 of the conventional processes and this means water and energy savings as well as the less effluent. The single-bath combined process is more advantageous dyeing technique about saving of time, water, energy and chemicals.

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