 ISSN - 2250-1991 | IF : 5.761 | IC Value : 79.96

Original Research Paper Engineering

PROTIC IONIC LIQUIDS AS ECOFRIENDLY DYEING MEDIUM FOR POLYESTER FIBERS

Rebecca S. Andrade CETENS, Universidade Federal do Recôncavo da Bahia, Feira de Santana, Brasil, Dpto. de Engenharia Química, Universidade Federal da Bahia, Salvador, Brasil.

Miguel Iglesias Dpto. de Engenharia Química, Universidade Federal da Bahia, Salvador, Brasil.

ABSTRACT

This paper contains the results of a new experimental study of dyeing polyester fibers using an ecofriendly process with protic ionic liquids (PIL´s) as dyeing medium. Our work was focused on the effects of washing temperature of dyed fabric and chemical structure of the dyeing ionic medium on relative strength of color, expressed by its K/S value, which was measured by means spectral analysis of polyester fabric dyed by Blue Sidersperse PFBG. Color strength of the dyed samples was stronger for the shortest chains protic ionic liquids and low temperature washing process. With the aim of analysing the quality of the dyeing ionic process for polyester textile industry at different operation conditions in terms of mechanical characteristics, a tensile strength test of the dyed fibers was made. The obtained experimental data prove the efficiency of PIL´s as dyeing vectors for dispersive colorants and polyester fibers.

KEYWORDS protic ionic liquids, dyeing, tensile strength test, ecofriendly process

INTRODUCTION

Dyeing processes are extremely important for marketing and differentiation of textile products. The dyeing occurs through the fixation of the dye molecules into the textile fibers, usually using water as the main solvent in the process [1]. The temperature and dyeing residence time are key factors, as well as, the nature of the dyeing solvent. Currently, there is great interest in finding environmentally friendly substances for this process, with a double practical objective, reduce the huge water consumption into textile processes and improve dyeing without damaging the quality of the fabric. Ionic liquids are versatile new media for many chemical processes, enzymatic catalysis, clean solvents and other applications [2]. Ionic liquids can be used as robust solvents due to their wide liquid window when compared with other conventional organic solvents. The additional advantage of their almost negligible vapor pressure, makes them solvents really attractive not only for its functionality, but also for its advantages in terms of environmental and safety.

The protic ionic liquids show additional advantages due to their simple chemical synthesis, low cost of production and biodegradability [3]. As a continuation of previous works on protic salts [4-5], in this work we propose an alternative and ecofriendly procedure to dye polyester fibers using new protic ionic liquids (PIL´s), namely 2-HDEAA (2-Hydroxidiethanolamine acetate), 2-HDEAAd (2-Hydroxidiethanolamine adipate), 2-HDEAF (2-Hydroxidiethanolammine formate), 2-HDEAL (2-Hydroxidiethanolammine lactate), 2-HDEAMa (2-Hydroxidiethanolammine maleate), 2-HDEAOx (2-Hydroxidiethanolammine oxalate), 2-HDEAPr (2-Hydroxidiethanolammine propionate), 2-HDEASa (2-Hydroxidiethanolammine salicylate), 2-HDEASu (2-Hydroxidiethanolammine succinate), 2-HEAA (2-Hydroxiethanolammine acetate), 2-HEAAd (2-Hydroxiethanolammine adipate), 2-HEACi (2-Hydroxiethanolammine citrate), 2-HEAF (2-Hydroxiethanolammine formate), 2-HEAL (2-Hydroxiethanolammine lactate) and 2-HEAPr (2-Hydroxiethanolammine propionate) as solvent substitute for water. Dye concentration and dyeing residence time were optimized to maximize colorant fixation, being analyzed the washing temperature of dyed fabric and chemical structure of the dyeing protic ionic liquid medium in terms of influence on relative color strength and color coordinates which were examined by means spectral analysis of polyester fabric dyed by Blue Sidersperse PFBG. With the aim of analysing the quality of the studied PIL's as dyeing solvents for polyester textile industry at different operation conditions, in this work we applied a tensile strength test of the dyed fibers. The obtained experimental data prove the efficiency of PIL´s as dyeing vectors for dispersive colorants and polyester fibers.

EXPERIMENTAL

- **Protic ionic liquids synthesis**

Mono and diethanolamine better than 98.0% was placed in a threenecked flask all-made-in-glass equipped with a reflux condenser, a temperature sensor and a dropping funnel. The flask was mounted in an ice bath. The different organic acids (>98.0%) were added drop wise to the flask under stirring with a magnetic bar. Strong agitation, low pressure and slight heating for total vaporization of residual non-reacted acid was applied at least for 72 h for purification, this process let us obtain a constant value of the physical properties of the pure salt [4-5].

- **Experimental dyeing**

The dyeing process was carried out with polyester fabrics and a Blue Sidersperse PFBG dye, which was provided by Siderquímica, Paraná, Brazil. The dye concentration was 2% w.w. (polyester fabric weight versus dye weight), the ratio R:B (polyester fabric versus bath weight) was fixed in 1:20, and the dyeing temperature was set at 330.15 K, according to the commercial practice of polyester dyeing industrial process.

Experimental tests were carried out in a reactor routinely employed in laboratories of textile research. Initially, the disperse dye is added to the dyeing reactor with the corresponding protic ionic liquid in the proportions previously indicated. The solubilization of the dye into the protic ionic liquid is initiated with a slight heating and strong mechanical stirring. After this time, the fabrics were added in pairs to the dyeing bath (protic ionic liquid + dye). The dyeing residence time was fixed in 60 minutes in order to reach the highest coloristic intensity values. Each pair of fabrics was dyed using a specific protic ionic liquid, and immediately afterwards, the samples were washed off using standard detergent aqueous solution (1 g/L) at a liquor ratio of 20:1 (distilled aqueous wash solution weight versus polyester fabric weight) for 30 minutes at 298.15 K (cool washing condition) and 330.15 K (hot washing condition), in order to eliminate any trace of protic ionic liquid or unfixed dye and to compare the effect of the washing temperature in the dyeing quality. Blank experiments were carried out under identical conditions, replacing protic ionic liquid by the equivalent quantity of water.

- **Color measurements**

Color strength of the dyed fabric samples was analyzed by using a

DATACOLOR™ 550 spectrophotometer. Reflectance measurements are often applied to determine the color strength to dyes adsorbed in a substrate, so all the dyed fabric samples were directly monitored at the wavelength of minimum absorbance (440 nm). Values of K/S were calculated by using the extensively reported expression of Kubelka–Munk (Equation 1):

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

where R is the measured reflectance, and K and S are the light absorption and the scattering coefficients of the dyed fabric, respectively. In addition of reflectance values, the spectrometer provide the tristimulus values (X, Y, Z), which were then transformed into the L*a*b* color space. Defined by the Commission Internationale de l'Eclairage (CIE), the L*a*b* color space (CIEL*a*b*) was modeled after a color-opponent theory stating that two colors cannot be red and green at the same time or yellow and blue at the same time. The parameter L* indicates lightness, a* is the red/green coordinate, and b* is the yellow/blue coordinate.

- Physical properties of samples

A tensile resistance test was performed on a dynamometer (MAQTEST®) following method ASTM D5035-95. The specimen gauge length used was 100 mm, with the cross-head speed fixed at 200 mm min^{-1}.

RESULTS AND DISCUSSION

The dyed polyester fabrics were evaluated for their color strength and color appearance indicated by K/S and L*a*b* values. These readings were taken at the peak wavelength, 440 nm. K/S values of dyed polyester fibers in ionic dyebath were significantly higher than the K/S values of the samples dyed on aqueous medium under both washing conditions, except for 2-HDEAMa and 2-HDEASa (in case of cool washing) and 2-HEAAd, 2-HEACi, 2-HDEAMa and 2-HDEASa (in case of hot washing) (Figure 1). In general, the values of K/S of the cool-washed samples were higher than the values of the hot-washed samples, what can be explained by the increase of solubility of the dye in the washing-water at higher temperatures. In terms of perceptual color, the dyeing quality could be best evaluated by analyzing the CIEL*a*b* color space (Figure 2).

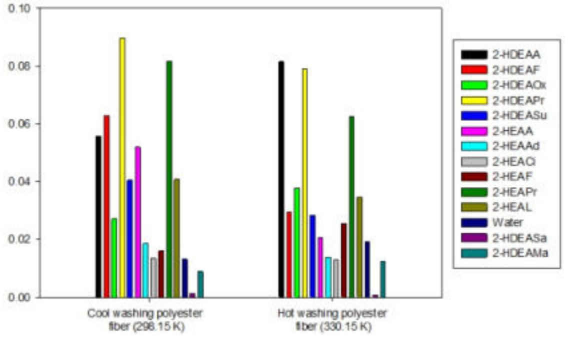

Figure 1: Comparison of K/S results for the different protic ionic liquids used as dyeing medium for polyester fibers

In Figure 2 (b-c), the axis (+a/-a) showing the approximate red/green dimension and the other axis *(-b/+b)* showing the approximate blue/yellow dimension. A third dimension, called L*, provides an achromatic measurement from black to white (Figure 2a). Polyester fabrics dyed into 2-HDEAPr and 2-HDEAA have a much more blue (Δb* > 5) and slightly red (Δa* < 0.8) appearance than the aqueous-medium dyed samples, for both washing cases. In terms of L* parameter, higher reflected luminance were observed for 2-HDEAMa and 2-HDEAOx, which confirms the lower K/S values, especially for the samples washed at higher temperature (high L* values indicate a more white sample).

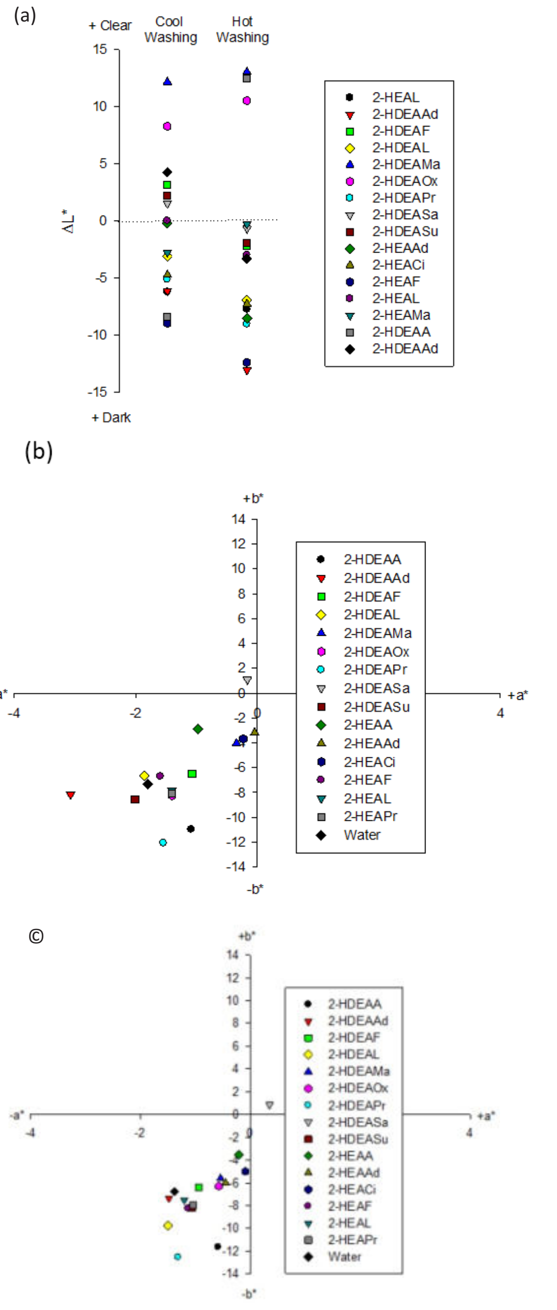

Figure 2: (a) Values of DL* (ΔL* sample minus L* standard) and CIEL*a*b* plots for (b) cool washing and (c) hot washing polyester fibers dyed for different protic ionic liquids.

The use of PIL as dyeing bath only slight modifies the mechanical properties of the fabric in comparison with aqueous-medium dyed polyester. Table 1 shows that the tensile properties (in terms of both tensile resistance and stretching gain) diminish slightly as a consequence of replacing water in the process, except for 2-HEACi and 2-HDEASa for cool washed samples, and 2-HDEASa and 2-HDEAMa for hot washed samples.

Diminution in tearing strength after PIL dyeing is probably due to the ionic modification of artificial fibers, reducing yarn and fiber slippage, resulting in less efficient redistribution of stress concentrations throughout the sample. The largest decrease in tearing strength was observed for samples dyed in 2-HEAA (cool washed) and 2-HDEAPr (hot washed).

TABLE – 1

TENSILE STRENGHT ASSAY PROPERTIES

PIL	Max. Peak (N)	Displacement (mm)	Stretching %
Cool Washing Fabrics			
2-HEAPr	33.26	86.02	286.73
2-HEAL	33.94	64.06	213.53
2-HDEACi	45.13	86.48	288.27
2-HDEAF	46.50	74.51	248.37
2-HDEAL	42.18	67.63	225.43
2-HDEAMa	48.95	70.44	234.80
2-HDEAOx	40.52	74.82	249.40
2-HDEAPr	47.77	75.16	250.53
2-HDEASa	43.07	170.00	566.67
2-HDEASu	45.91	73.13	243.77
2-HEAA	42.38	60.96	203.20
2-HEAAd	45.32	68.05	226.83
2-HEACi	53.96	159.17	530.57
2-HEAF	43.07	81.25	270.83
Water	46.60	152.40	508.00
Hot Washing Fabrics			
2-HEAPr	38.95	83.23	277.43
2-HEAL	40.12	73.12	243.73
2-HDEAAd	47.68	74.43	248.10
2-HDEACi	39.93	63.64	212.13
2-HDEAL	42.87	64.27	214.23
2-HDEAMa	52.78	168.65	337.30
2-HDEAOx	39.63	149.69	299.38
2-HDEAPr	43.95	60.21	200.70
2-HDEASa	52.39	157.14	523.80
2-HDEASu	25.41	158.49	316.98
2-HEAA	47.87	71.72	239.07
2-HEAAd	44.24	72.55	241.83
2-HEACi	38.65	161.20	322.40
2-HEAF	33.35	266.15	532.30
Water	51.01	84.64	262.13

CONCLUSIONS

This paper contains the results of a new experimental study of dyeing polyester fibers using an ecofriendly process with protic ionic liquids (PIL´s) as dyeing medium. Analyzing the experimental results, it should be concluded the following points:

- The dyed samples into ionic medium were tested in a reflectance spectrophotometer to obtain the difference in color coordinates. In general, color strength of the dyed samples was stronger for samples dyed into the shortest chain protic ionic liquids and low temperature washing processes.

- The tensile strength test of the dyed fibers showed an diminution in tearing strength after dyeing into the studied PILs (except for 2-HDEASa, 2-HDEAMa and 2-HEACi), indicating a probable change in a fiber structure of the samples.

- The obtained experimental data prove the efficiency of PIL´s as dyeing vectors for dispersive colorants and polyester fibers.

REFERENCES:

1. Koh, J. (2011), "Textile dyeing." Ed. Peter J. Hauser.
2. Plechkova, N.V. and Seddon, K.R. (2008), "Applications of ionic liquids in the chemical industry." Chem. Soc. Rev. 37, 123-150
3. Greaves, T.L. and Drummond, C.J. (2008), "Protic ionic liquids: Properties and applications." Chem. Rev. 108, 206-237
4. Alvarez, V.H., Mattedi, S., Martin-Pastor, M., Aznar, M. and Iglesias, M. (2011) "Thermophysical properties of binary mixtures of {ionic liquid 2-hydroxy ethylammonium acetate + (water, methanol, or ethanol)}." J. Chem. Thermodyn. 43, 997-1010
5. Cota, I., Medina, F., Gonzalez-Olmos, R. and Iglesias, M. (2014) "Alanine-supported protic ionic liquids as efficient catalysts for aldol condensation reactions." C. R. Chim. 17, 18-22