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The clearing of poly(lactic acid) fibres dyed with disperse dyes using ultrasound: Part 2 – fastness

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Abstract

Of the three types of clearing processes (water, ECE detergent and reduction clearing) applied to dyeings of six disperse dyes on PLA, water had little effect on fastness to both rubbing and repeated washing; reduction clearing was slightly more effective than ECE detergent in improving wash fastness whilst the detergent imparted higher levels of rub fastness. Both wash and rub fastness were higher when aftertreatment was carried out at 60 °C rather than at 50 °C. Ultrasound enhanced the effectiveness of both reduction clearing and ECE detergent in terms of rub fastness and enabled a modified reduction clearing process to be used that employed lower amounts of alkali and reducing agent. This offers the potential for reducing the BOD, COD, TOD and amount of suspended solids that are generated during the reduction clearing of disperse dyes from dyed PLA. The colour of the five times washed dyeings was unaffected by the aftertreatment used.

Keywords: Ultrasound; Disperse dyes; PLA fibre; Dyeing; Fastness

1. Introduction

Differences exist between the dyeability of the aliphatic, thermoplastic polyester, poly(lactic acid) (PLA) and that of it's more famous and far more well-established polyester similitude, poly(ethylene terephthalate) (PET). Owing to the marked hydrolytic sensitivity and the lower T_m of PLA fibres (~170 °C for PLA versus 250–260 °C for PET), the dyeing conditions that are commonly used for the application of disperse dyes to PET (high temperature dyeing at 125/130 °C and thermofixation at ~210 °C) cannot be employed for PLA. Consequently, dyeing conditions of 110–115 °C for 15–30 min at pH 4.5–5 have been recommended for PLA fibres [1]; the use of higher temperatures, longer times of dyeing at 110–115 °C or higher pH can lead to fibre hydrolysis. As in the case of PET which has been dyed with disperse dyes, a reduction clearing treatment is needed to remove surplus dye and auxiliaries from dyed PLA. However, the greater hydrolytic sensitivity and lower T_g of PLA (55–65 °C for PLA versus 80–90 °C in the case of PET) dictate that more weakly alkaline conditions (Na_2CO_3 rather than NaOH) [1,2] and lower temperatures (60 °C for PLA versus 60–80 °C for PET) [1,2] for 15 min [1,2] be employed for PLA which has been dyed with disperse dyes.

In the context of the susceptibility of PLA to hydrolysis, it was decided to establish whether or not a less severe clearing treatment (in terms of temperature and chemicals) could be devised for PLA via the well-known ability of ultrasound to enable the attainment of similar/improved results under less extreme conditions. In the first part of this paper [3], three types of clearing processes namely water, ECE detergent and reduction clearing were used to aftertreat six disperse dyes on PLA fibre. While reduction clearing imparted the greatest changes to both the colour strength and colour of the dyeings, treatment with ECE detergent also removed surplus dye and improved the chroma of the dyeings; treatment with water had very little effect on the colour strength and colour of dyeings, even in the presence of ultrasound. It was

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found that both depth of shade reduction and colour change were greater when aftertreatment was carried out at 60 °C rather than at 50 °C and that ultrasound neither impaired nor overly enhanced the effectiveness of either the ECE detergent or the reduction clearing processes.

This part of the paper concerns the effect of the three clearing processes (water, ECE detergent and reduction clearing) on the fastness of the six disperse dyes on PLA fibre to repeated washing and to rubbing.

2. Experimental

2.1. Materials

Scoured, poly(lactic acid) knitted fabric (which was obtained from NatureWorks LLC) described earlier [3] was used. Commercial samples of the six disperse dyes shown in Table 1 were generously supplied by DyStar and Clariant; the dyes were used without purification. All other chemicals were of general laboratory grade supplied by Aldrich.

2.2. Dyeing

Using the equipment described earlier [3] following the method shown in Fig. 1, 2% omf depths of shade were produced; the pH was adjusted using acetic acid/sodium acetate buffer.

2.3. Clearing treatments

Each of the 2% omf dyeings was subjected to the various treatments listed in Table 2, using the equipment and following the methods shown in Figs. 2 and 3, as described previously [3]. A Grant MXB22 ultrasound bath was used.

2.4. Colour measurement

All measurements were carried out using the equipment and procedures described earlier [3].

2.5. Wash fastness

The wash fastness of the dyed samples was determined using the ISO CO6/B2S (50 °C) test method [4] but was modified in that dyeings were subjected to five, consecutive wash tests and, at the end of each wash test, the washed sample was rinsed thoroughly in tap water (but was not dried) and a fresh sample of SDC multifibre strip was used to assess the extent of staining for each of the five wash tests.

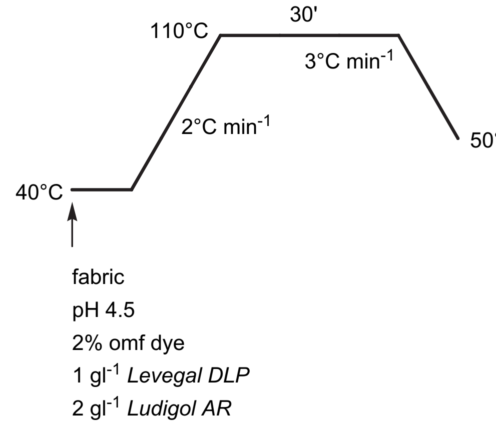

Fig. 1. Dyeing method.

2.6. Rub fastness

Both the dry and wet rub fastness of the dyed PLA samples were determined using the ISO 105:X12 test method [4].

3. Results and discussion

Six dyes were selected for use on the basis that they provided two representatives of low, medium and high energy classes of disperse dye; a 2% omf depth of shade was used as this provided typical medium depth dyeings. A repeated wash fastness protocol was employed, rather than a single wash test, as it was considered to more accurately reflect the progressive nature of the removal of dye and the redeposition of vagrant dye that occurs during domestic washing.

Table 3 shows the extent of staining, by vagrant dye, of multifibre strip that occurred during the five, consecutive wash tests as well as the shade change obtained during repeated washing in the case of C.I. Disperse Blue 56. It is clear that the non-aftertreated dyeing displayed moderate fastness to repeated washing at 50 °C, as evidenced by the high level of staining of the adjacent multifibre strip imparted by dye which

Table 1
Dyes used

Commercial name	C.I. generic name	Energy level	Supplier
Foron Brilliant Red E-2BL 200	Disperse Red 60	Low	Clariant
Foron Blue E-BL 200	Disperse Blue 56	Low	
Foron Yellow SE-FL	Disperse Yellow 42	Medium	
Foron Rubine S-GFL 150	Disperse Red 167:1	High	
Dianix Yellow Brown CC	None ascribed	Medium	DyStar
Dianix Crimson SF	None ascribed	High	

Table 2
Clearing treatments used

	Treatment	Temp. (°C)
None		
Absence of ultrasound	ECE detergent	60
	'Standard' reduction clear	
Presence of ultrasound	ECE detergent	60
	Modified reduction clear	
	Water	50
	ECE detergent	
	Modified reduction clear	