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The clearing of poly(lactic acid) fibres dyed with disperse dyes using ultrasound: Part 3

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Abstract

The effectiveness of an ultrasound-assisted, ECE detergent-based aftertreatment was found to be little improved by the use of temperatures higher than 60 °C, durations longer than 5 min and detergent concentrations greater than 2 g l^{-1}. As little difference was found between the effectiveness of the detergent aftertreatment and that of the traditional reduction clearing process, it appears that, in terms of fastness and colour, the Na_2CO_3 and $Na_2S_2O_4$ used in the reduction clearing of disperse dyed PLA fibre can be replaced with a treatment using 2 g l^{-1} ECE detergent in the presence of ultrasound. This alternative aftertreatment of dyed PLA may offer a reduced risk of hydrolytic damage to the fibre as well as reduced chemical consumption and also generate a more environmentally acceptable effluent than reduction clearing.

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

1. Introduction

A reduction clearing treatment is needed to remove surplus dye and auxiliaries from poly(lactic acid) (PLA) which has been dyed with disperse dyes. Owing to the hydrolytic sensitivity and T_g of PLA, reduction clearing comprises, typically, of submitting the rinsed, dyed material to treatment for 15 min at 60 °C in an aqueous bath containing 1.5–2 g l^{-1} Na_2CO_3 and 2 g l^{-1} $Na_2S_2O_4$ [1,2]. However, the use of sodium dithionite produces environmentally unfriendly effluent which, in the case of azo disperse dyes, may also contain aromatic amines [3]. In this latter context, together with the susceptibility of PLA to hydrolysis, it was decided to establish whether or not a clearing treatment could be developed for dyed PLA which offered a low risk of hydrolytic damage and which constituted a more environmentally friendly approach as well as reduced chemical usage. To this end, the decision was made to determine if the well-known abilities of ultrasound (process acceleration and the attainment of similar/improved results under less extreme conditions) would enable both the Na_2CO_3 and $Na_2S_2O_4$ used in reduction clearing to be replaced by an aftertreatment with a common detergent formulation.

In the first part of this paper [4], three types of clearing process namely water, reduction clearing and ECE detergent, were used to aftertreat six disperse dyes on PLA fibre. Although 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 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. The second part of the paper [5] revealed that reduction clearing was slightly more effective than ECE detergent in improving wash fastness whilst ECE detergent imparted higher level of rub fastness; water had little effect on fastness to both rubbing and repeated washing. Both wash and rub

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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	

fastness were higher when aftertreatment had been 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 final part of the paper concerns the effects of varying the amount of ECE detergent used as well as different times and temperatures of aftertreatment on the fastness of three disperse dyes to both rubbing and repeated washing.

2. Experimental

2.1. Materials

Scoured, poly(lactic acid) knitted fabric (which was obtained from NatureWorks LLC) described earlier [1] was used. Commercial samples of the three disperse dyes shown in Table 1 were generously supplied by Clariant and were used without purification; the three dyes were selected for use on the basis that they were representative of contemporary disperse dyes. ECE detergent was obtained from the Society of Dyers and Colourists; all other chemicals were of general laboratory grade supplied by Aldrich.

2.2. Dyeing

Dyeings of 1% and 2% omf were produced, using the equipment described earlier [1] following the method shown in Fig. 1; the pH was adjusted using acetic acid/sodium acetate buffer. The dyeings were rinsed thoroughly in tap water and allowed to dry in the open air.

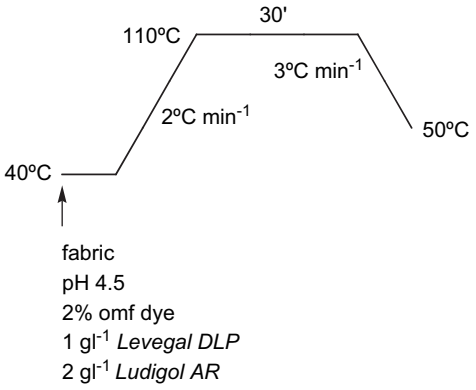

Fig. 1. Dyeing method.

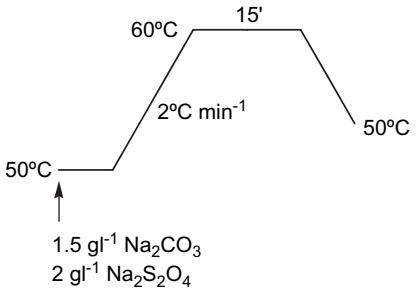

Fig. 2. Reduction clearing method.

2.3. Aftertreatments

2.3.1. Reduction clearing

Dyeings were reduction cleared, in the absence of ultrasound, using the equipment described earlier [2] following the method shown in Fig. 2.

2.3.2. ECE detergent

Dyeings were treated using 2, 4 and 8 g l^{-1} ECE detergent, at 60, 70 and 80 °C for 5, 15 and 30 min, using the method shown in Fig. 3, employing the equipment described before [2] in the presence of ultrasound provided by a Grant MXB22.

2.4. Colour measurement

All measurements were carried out using the equipment and procedures described earlier [1].

2.5. Wash fastness

The wash fastness of the dyed samples was determined using the ISO CO6/B2S (50 °C) test method but was modified such 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 [2].

2.6. Rub fastness

The dry and wet rub fastness of the dyed PLA samples were determined using the ISO 105:X12 test method [2].

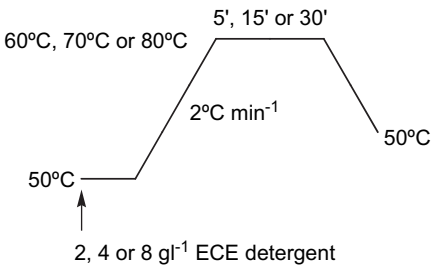

Fig. 3. Aftertreatment using detergent.