Non-aqueous Wool Fiber Dyeing Process Using Reverse Micellar Approach

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ABSTRACT

This study will explore the novel wool dyeing process in non-aqueous medium using nonionic surfactant as a carrier for stable encapsulation of reactive dyes. The objectives of this study are: (i) to develop non-aqueous dyeing system for wool fibre with reactive dyes using nonionic surfactant as carrier and (ii) to study the dyeing performance of the developed non-aqueous dyeing system for wool fibres with reactive dyes. It is expected that the outcomes of this study can achieve: (i) simplify the conventional wool dyeing process with reactive dyes when using water; (ii) lower the dyeing temperature; (iii) eliminate the use of auxiliaries and (iv) reduce wastewater discharge.

Keywords: Wool fibre, non-ionic surfactant, non-aqueous dyeing, reverse micelle, reactive dye

1 INTRODUCTION

Wool consists principally of one member of a group of proteins called keratins. Keratin macromolecules are crosslinked with cystine residues and contain a variety of side chains, some basic and some acidic [1]. Wool fibres consist of cortical cells and cuticular cells, which are located in the outermost part of the fibre surrounding the cortical cells. They consist of endocuticle, A and B exocuticle, and an exterior hydrophobic thin membrane called the epicuticle [2]. Both layers have a tremendous influence on dyeing because of their hydrophobic characteristics. The cuticle is separated from the underlying cortex by the intercellular material, which is called the cell membrane complex (CMC) and consists of non-keratinous proteins and lipids [1]. The morphology of the wool fibre surface plays an important role in textile finishing processes. The covalently bound fatty acids and the high amount of disulphide bridges make the outer wool surface highly hydrophobic. Especially in the printing and dyeing of wool, the hydrophobic character of the wool surface is disturbing. Diffusion of the hydrophilic dyes at and into the fibres is hindered. For this reason, the hydrophilicity and dyeability properties of the wool fibre should be developed [3]. Wool dyeing is a degradative process involving high temperature for long period in acidic to neutral pH medium to achieve good penetration, optimum fastness, and dye uptake. The results can be harsh handle, discomfort, and deterioration of properties that impact consumer wear, care, and aesthetic appreciation [4].

The conventional method of producing fast dyeings on wool is to employ dyes possessing large organic functional groups, metallized or metallizable dyes. In these systems, the high wet fastness is achieved by using dyes possessing a very slow rate of diffusion through the wool fibre. However, wet fastness, with reactive dyes, does not depend upon a slow rate of diffusion of the dye through the fibre, but upon the formation of a stable chemical bond between fibre and dye. Wool dyeing with reactive dyes is generally performed in water-based dye bath. In such a process, aqueous waste effluent containing excess dye residues and concentrated electrolytes may cause environmental problems. In addition, during dyeing in water-based system, some problems such as shrinkage, unlevel dyeing and fibre damage may occur which may affect the performance of dyed wool fibre. Thus, it is necessary to introduce novel dyeing method for wool fibre. In recent years, novel concepts in the textile dyeing technology that utilised minimal amount of water so-called non-aqueous dyeing technology are currently investigated and evaluated. In this novel concept, the textile dyeing is carrying out using reverse micelle system in organic solvent as the dyeing medium [5, 6]. The reverse micelles have a remarkable property of solubilising small amount of water in the interior of a micelle to provide a stable aqeous micro-environment, a so-called water-pool, in non-aqeuous media [5, 6] (Figure 1). The reverse micelle therefore has the potential to solubilize hydrophilic substances in non-aqueous media. cotton fibre with good results. Since the reverse micelle dyeing system in non-aqueous medium does not involve the use of water for dyeing, the problems associated with water-based dyeing in wool fibre can be eliminated.

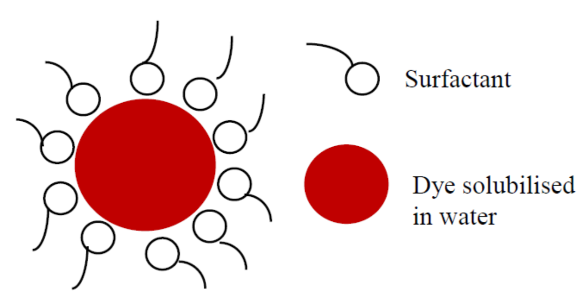

Figure 1: Dye in reverse micelle

Therefore, this study will investigate to use the reverse micelle system as non-aqueous dyeing system for dyeing wool fibre with reactive dye. This study will explore the using non-aqueous solvent for wool dyeing which involves nonionic surfactant as dye encapsulant with minimum water usage and no electrolyte and pH adjustment are required.

2 DYEING PROCESSES

The dyeing profiles of conventional water-based dyeing and non-aqueous reverse micellar approach dyeing of wool fiber are shown in Figure 2 and Figure 3 respectively.

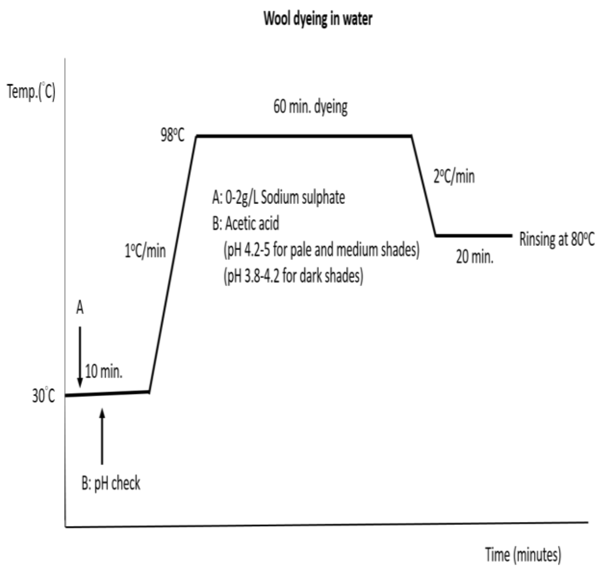

Figure 2: Coventional water-based wool dyeing

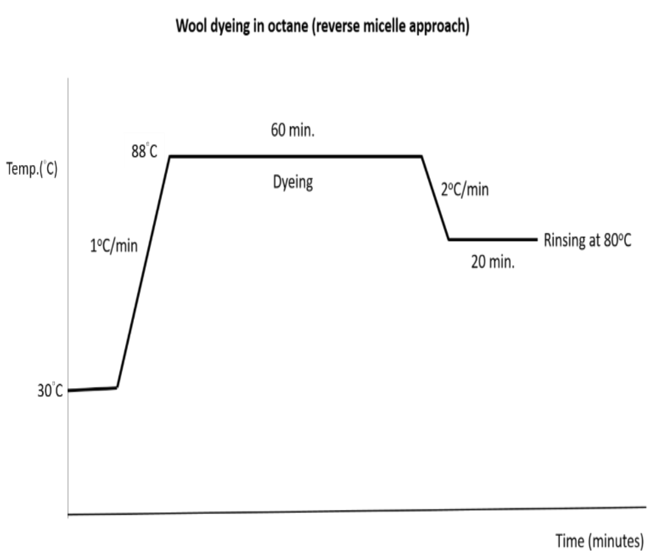

Figure 3: Non-aqueous reverse micellar approach wool dyeing

3 FINDINGS

Reactive dye encapsulated in reverse micelle using non-ionic surfactant was used as an environmental friendly for sustainable textile coloration of wool fabric with primary emphasis on highly reduction of water usage for the solubilization of reactive dyes. The working temperature of non-aqueous dyeing is 88°C (Figure 2) which is 10 degrees lower than in conventional water-dyeing process in terms of energy saving aspect (Figure 1).

Wool dyeing using reverse micellar approach can be achieved without addition of salt and pH adjustment (minimization of the waste products and waste treatment cost). Wool dyeing using reverse micellar approach can be accomplished at lower temperature than conventional aqueous dyeing in terms of energy saving point of view.

Figure 4 and Figure 5 show the color strength of conventional water-based dyed and non-aqueous reverse micellar approach dyed wool fiber respectively. The obtained color strength in the case of reverse micellar approach (Figure 5) is better than that in conventional aqueous dyeing (water-based dyeing) (Figure 4). Dyeability of wool fibre with reactive dye from the reverse micellar solution was improved without incorporation of textile auxillaries such as electrolytes and chemicals such as acetic acid or sodium bicarbonate for pH adjustment. Optimization of dyeing and fixation process could be achieved in a one-bath reverse micelle solution, leading to a potential of lowering the operation costs and energy consumption.

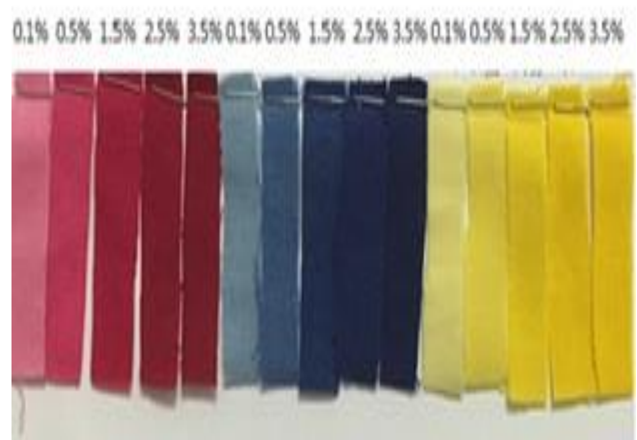

Figure 4: Color strength of conventional water-based dyed wool fiber

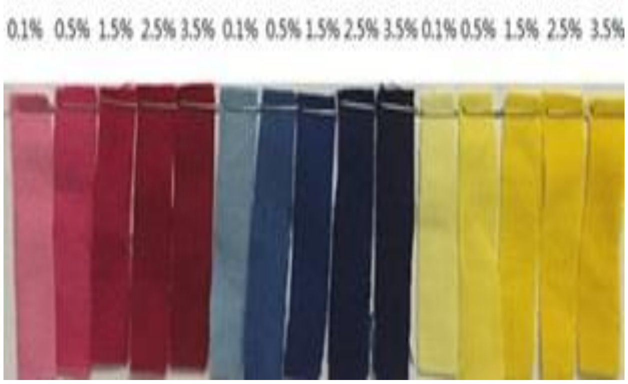

Figure 5: Color strength of reverse micellar approach dyed wool fiber

The used solvent can be recycled and reusable without generation of dye wastewater effluent. Figure 6 and Figure 7 show the dyeing residues of conventional water-based dyeing and non-aqueous reverse micellar approach dyeing of wool fiber respectively.

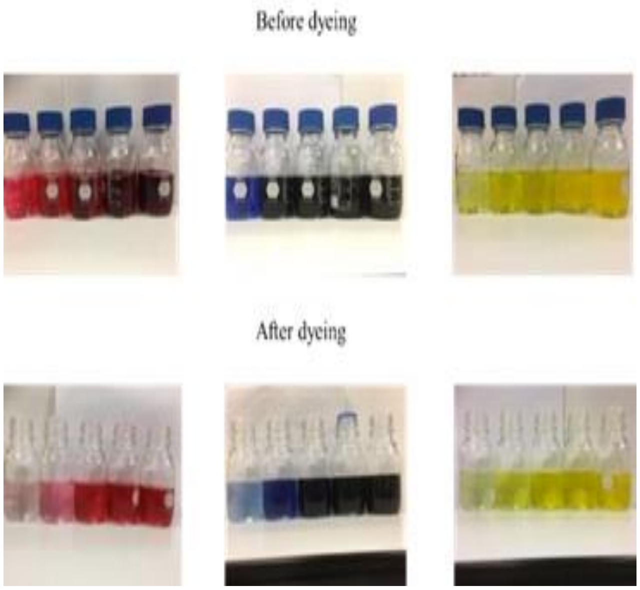

Figure 6: Dyeing residues of conventional water-based dyeing

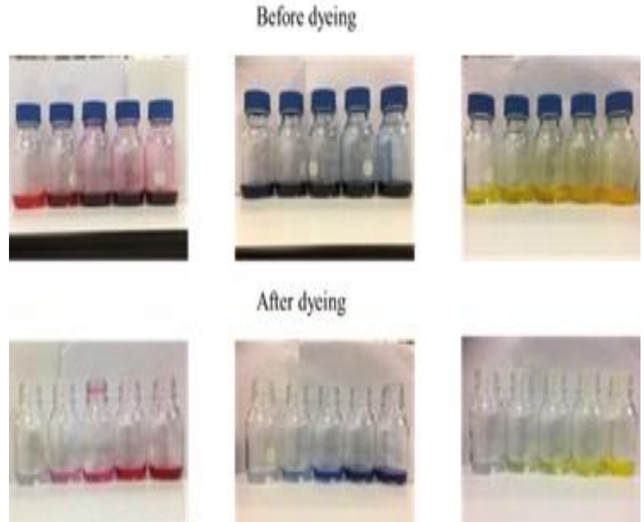

Figure 7: Dyeing residues of non-aqueous reverse micellar approach dyeing

4 CONCLUSION

This study has the following estimated significance and value:

(a) In this study, it aims to develop reactive dye dyeing system for wool fibre in a simplified approach. With the use of recyclable and reusable solvent, it is strongly believed that the effluent discharges can be highly reduced under the usage of minimal water content and eliminating the possible contamination caused by dye auxiliaries and unfixed hydrolyzed dyes.

(b) The use of nonionic surfactant as building block for dye carriers in reverse micellar form could achieve faster dyeing with less energy consumption. As conventional water-based dyeing system requires large amount of water in the process, the reverse-micellar system may highly reduce water and energy via short liquor-to-goods ratio thus energy-efficient dyeing can be achieved.

(c) Dyeing system using reverse micelle as dye carrier could lead to better levelness and colour yield. It is believed that the dyeing technique could be improved by lowering the possibilities of non-uniformity of dyes during the dyeing process and the system can be further optimized for better exhaustion and improved the diffusion properties of reactive dyes in wool fiber matrix.

(d) With the introduction of reverse-micellar dyeing system, it is believed that the fabric aesthetics could be controlled. As the dyeing process condition, dyeing defects due to materials, water quality and improper dye solution, are frequently occurred in conventional water-based dyeing, could be eliminated so that the aesthetics of fabric could be well manipulated.

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