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ORIGINAL ARTICLE

The application of poly(amidoamine) dendrimers for modification of jute yarns: Preparation and dyeing properties

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Abstract In this study, poly(amidoamine) (PAMAM) G-2 dendrimer was used for jute yarn. Fourier transform infrared spectroscopy (FT-IR) revealed that all carbonyl groups of jute fibers reacted with amino groups of polyamidoamine dendrimers. SEM observation indicated the good dispersion PAMAM dendrimers. Jute yarns pretreated with PAMAM dendrimer displayed markedly enhanced color strength with reactive dyes, even when dyeing had been carried out in the absence of electrolyte or alkali. Dendrimer-treated jute yarn showed much better light-fastness than untreated jute yarn.

1. Introduction

Colouration of jute fabric has become essential for all sorts of fabric, starting from decorative value added fabrics to attractive packaging material. Due to the eco-friendly and biodegradable nature of jute fiber, the demand for jute fabric is rising worldwide day by day. One of the major problems that restrict the uses of jute products is that jute suffers seriously from light induced discoloration, due to the phenolic structures of lignin (Cai et al., 2000; Callow and Speakman, 2008).

In case of dyeing of jute with reactive dyes, dyes reacts with hydroxyl group of the fiber by either substitution or addition reactions (Chattopadhyay et al., 2006). For reaction with cellulosic fibers, reactive dyes typically rely on an elevated pH (commonly over 10.5) and large amounts of electrolyte (NaCl or Na_2SO_4) to overcome the static repulsion between cotton fibers and reactive dyes in order to promote dyeability. During their application, along with dye absorption, dye hydrolysis also takes place. Greatest problem is dye hydrolysis or the reaction of dyes with water, since hydrolysis blocks the reactive sites so that the dyes cannot covalently bond with

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fibers. The hydrolyzed dye retains on the fabric and is removed by severe washing. This results in wastage of dye. Hydrolysis of the dye by water is more rapid at higher pH values. The application of reactive dyes to cellulosic fibers continues to be costly for the dye house in terms of dye wasted, electrolyte and alkali used. In addition, it results in an increase of pollution load in the environment (Burkinshaw et al., 2000).

An alternative approach to increase dye uptake and dye fixation is the modification of cellulosic fibers themselves. In essence, attention has focused on the introduction of cationic groups by means of pretreatment, commonly via quaternised amino groups, to which the anionic reactive dyes are attracted and so enhance dye-fiber substantivity. Such enhanced dye-fiber substantivity can result in reduced electrolyte usage and, potentially at least, lead to salt-free dyeing. In addition, if the cationic pretreatment compound also contained nucleophilic groups, such as primary amine or thiol, it is possible that the reactive dye could react with such added nucleophiles at lower pH values than are normally needed for cellulosic fiber dyeing; this, in turn, could, theoretically, lead to reduced dye hydrolysis.

Dendritic polymers can be divided into two classes: dendrimers (branched uniform structure) and hyperbranched polymers (more random fashion). Dendrimers are a class of low-molecular weight highly branched polymers with several functional groups that have a central core and terminal end groups. They are generally prepared using either a divergent method or convergent method. In the divergent method, dendrimers grow outward from multifunctional core molecules, whereas in the convergent method, the dendrimer is constructed stepwise starting from the end group and moving inward (Blencowe et al., 2009). The nature of the outer functional groups determines the solubility and reactivity of the dendrimers. Each layer in a dendrimer is termed a single generation.

Because of their unique chemical and physical properties, dendrimers and hyperbranched polymers have received much attention over the past two decades and have been used in coatings, additives, drug and gene delivery, macromolecular building blocks, nanotechnology and supramolecular science.

Dendritic polymers are typical compounds used in this aspect. With smaller molecular size, these compounds present good penetrability in fiber, and the exhaustion and fixation of reactive dyes on the modified fiber have improved.

Salt-free/low-salt dyeing technology with reactive dyes has become a popular topic. Most researchers focus on introducing cationic groups like amino or ammonium groups into cotton fabrics for interactions with anionic dyes. Dendrimers dyeing pretreatment enhances colour strength of cotton fabric (Burkinshaw et al., 2000; Wei et al., 2005; Jockusch et al., 1995). Amino-terminated hyperbranched polymer (HBP-NH_2) grafted cotton fiber displays markedly enhanced color strength when dyed with reactive dyes using salt-free dyeing. The washing-fastness and rubbing-fastness of the dyed hyperbranched grafted cotton fabrics are also good compared with those obtained by conventional dyeing (Zhang et al., 2008).

In the presence of citric acid, the pretreatment of cotton with the amino-terminated hyperbranched polymers as cross-linking agents can also enhance the dyeability of the cotton fiber with reactive dyes (Zhang et al., 2007).

The use of dendrimers as an antimicrobial agent can be beneficial because of their unique structures (Ghosh et al., 2010). It is believed that dendrimers with amine functional groups could be converted to effective antimicrobial agents due to their dense primary amine functional groups. Dendrimers have some unique properties because of their globular shape and tunable cavities. It has also been shown that dendrimers are able to form complexes with a variety of ions and compounds and act as a template to fabricate metal nanoparticles (Balogh et al., 2001; Aymonier et al., 2002; Mahapatra and Karak, 2008; Prosycevas et al., 2010; Dastjerdi and Montazer, 2010).

The present work aimed to understand whether the pretreatment of jute yarns with dendrimers could improve its dyeability to reactive dyes. Color strength (*K*/*S*) and light-fastness (L.F.) of treated yarns were obtained and compared to conventional dyeing method. Dendrimer of generation 2 was used to study. Since, it is less dense than water, grafting treatment was performed in alcoholic media.

2. Experimental

2.1. Materials

C.I. Reactive Blue 19 and Reactive Yellow 176 were purchased from Nordex International D.Z.E company (UK). Levogen WRD-T (cationic detergent) was obtained from Bayer (Germany). All chemicals were used without any further purification. Commercially available tossa jute yarn with a twist 308 t/m and yarn count 4118 dTex was used throughout the study.

2.2. Dendrimer

Polyamidoamine (PAMAM) dendrimers of generation 2 with 16 surface groups, 3.256 molecular weight and 2.6 nm dendrimer were obtained from Institute for Color Science and Technology, Tehran, Iran (Khanafari and Ahmadi-Fakhr, 2010) (Fig. 2). The synthesis of poly(amidoamine) (PAMAM) dendrimer with ethylenediamine (EDA) core up to the second generation (G2) was performed using the divergent procedure presented by Esfand and Tomalia (2002).

2.3. Application of dendrimers

The jute yarns were first immersed into dendrimer–ethanol solution at concentration of 2.5% omf at room temperatures for 3 h, maintaining a liquor ratio of 15:1 (w/w). Next, they were air dried at room temperature for 24 h. The samples were then treated with the dendrimer in the oven at 100 °C for 50 min.

2.4. Dyeing

To highlight differences in dye uptake between the pretreated and untreated jute samples, the dyeing process was carried out using a competitive dyeing method in which both dendrimer-treated and untreated samples are dyed competitively in the same dyebath. Dyeing with reactive dyes was performed at a liquor ratio of 50:1. Dyeing of the samples was started at 30 °C for Blue 19 and Yellow 176, and at 60 °C for Blue 66 for 50 min. The samples were left at this temperature for 30 min in the presence of sodium chloride (60 g/l). Afterwards, sodium carbonate (20 g/l) was added for dye fixation and dyeing continued at 30 °C for another 30 min.