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Synthesis and application of new sizing and finishing additives based on carboxymethyl cellulose

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ABSTRACT

Ammonium persulfate $(NH_4)_2S_2O_8$ was used to initiate the polymerization of vinyl acetate (VAc) monomer in presence of carboxymethyl cellulose (CMC) to produce (CMC-g-PVAc) adduct under different conditions including, initiator concentration, temperature and time of polymerization, as well as VAc to CMC ratio. The produced adduct was further saponified to produce the adduct CMC-g-poly vinyl alcohol (CMC-g-PVA). Saponification was conducted in ethanol using 40% aqueous sodium hydroxide solution. IR spectra of CMC, CMC-g-PVAc adduct and CMC-g-PVA adduct were investigated. CMC and CMC-g-PVA adduct in comparison with a physical mixture of CMC and PVA (Vinarol STH) were utilized as a sizing or finishing agent for 100% cotton and 50/50% cotton/polyester blend. It was found that samples finished using the produced CMC-g-PVA adduct acquired better mechanical properties such as wrinkle recovery angle, tensile strength, dyeability and oily stain release than CMC alone or physical mixture with PVA. On the other hand, it appears that (CMC-g-PVA) adduct is a promising easily removals sizing agents.

1. Introduction

Polymerization of some functional monomers in presence of water soluble polymers and gums gives useful adducts of superior properties than those of the starting materials, such as polyacrylamide/guar gum adduct as a new thickener for reactive printing on wool and nylon 6 (Ibrahim, Rashad, & Abo-Shosha, 2003), polyacrylic acid/pyrodextrin adduct as cotton sizing agent (El-Sayed, Famy, Ibrahim, & Abo-Shosha, 2004), polyacrylic acid/polyvinyl alcohol adducts as cotton sizes (Hebeish, Fahmy, Abo-Shosha, & Ibrahim, 2006), polyacrylamide/polyvinyl alcohol as finishing additives (Ibrahim, Hebeish, Fahmy, & Abo-Shosha, 2006), polyacrylic acid/gum arabic as thickeners for reactive printing of cellulosic fabrics (Ibrahim et al., 2006b) and polyacrylic acid/karaya or tamarind gums as thickeners for testing of protein fabric (Abo-Shosha, Ibrahim, Allam, & El-Zairy, 2008).

This stimulates the present work, where VAc is polymerized in presence of CMC followed by saponification inorder to convert the acetate groups to hydroxyl groups to produce CMC-g-PVA adduct. Accordingly a polyblend of CMC and PVA is produced, i.e., a mixture containing mainly CMC, CMC-g-PVA and PVA. Accordingly, the aim of this work is to: (a) prepare polyblend of CMC and PVA, (b) utilize the obtained poly blend in sizing and finishing in comparison with their physical mixtures and (c) investigate the impact of using these poly blends as finishing additives on post basic dyeing.

2. Experimental

2.1. Materials and chemicals

100% cotton fabric (145 g/m) and (50/50%) cotton/PET were used. Sodium carboxymethyl cellulose (CMC C-30 under commercial name Taylose) was purchased from Hoechst. Vinyl acetate monomer contaning 14 ppm hydroquinone as inhibitor was provided by Aldrich. Ammonium persulfate, as initiator, ethyl acetate, magnesium chloride, as a catalyst, sodium carbonate, sodium chloride, sodium hydroxide, ethanol, acetic acid and hydrochloric acid were all of laboratory grade chemicals.

Arkofix NG-ET of Clariant (dimethylol dihydroxy ethylene urea), was used as a crosslinking agent. Hostapal CV, non-ionic wetting agent and Basic red 18 (Dyestar) and Vinoral STH (Hoechst Orient S.A.A.) were of commercial grade.

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2.2. Methods

2.2.1. Prewashing

The used fabrics were boiled in aqueous solution containing 2 g/L non-ionic detergent for 30 min, thoroughly rinsed and dried at ambient condition.

2.2.2. Graft copolymerization

VAc and ammonium persulfate mixture were poured into a conical flask, followed by posting CMC with that mixture. The temperature was raised to a specific value (30–80 °C). Polymerization reaction proceeded for a certain period from 20 to 180 min. PVAc homopolymer and unreacted monomer were removed from the obtained polymerization products by Soxhlet extraction with ethyl acetate for 2 h. The final polymer was then dried to a constant weight under vacuum.

2.2.3. Saponification of CMC-g-P VAc adduct

The Saponification process was carried out in absolute ethanol, according to the method described by Samaha et al. (2005). In a typical experiment, 5 g of the CMC-g-PVAc adduct were dispersed in 65 ml absolute ethanol, the obtained dispersion was placed in a round flask equipped with a condenser and mechanical stirrer. The temperature was adjusted to 40 °C. 1.25 ml of aqueous 40% NaOH was added to the mixture. The saponification took place, with precipitation of CMC-g-PVA adduct, in 3 min. After standing at room temperature for about an hour, the mixture was filtered, and then washed several times with methanol. The saponified adduct was also washed with ethanol/H_2O mixture (80/20) under mechanical stirring to extract VC-ONa and NaOH. Finally, CMC-g-PVA adduct (mixture of CMC and CMC-g-PVA and PVA homopolymer) was allowed to dry in air.

2.2.4. Sizing

Certain weight of the chemical mixture (CMC, CMC-g-PVA and PVA), CMC and physical mixture CMC/PVA were independently added to an agitated cold water bath and stirring was continued for 20 min to wet the granules, then the temperature was raised to 80 °C at a rate of 2 °C/min, where the cooking was continued for 30 min. After cooking, the samples of 100% cotton and 50/50% cotton/PET fabrics were fed into a pad box containing the size solution (5%) at a temperature of (80 °C), then run through pad rolls to squeeze out excess size to a wet pick up of ca. 100% and followed by drying at ambient condition for 24 h before testing.

2.2.5. Size removal

The reweighed-sized samples (W1) were subjected to washing with hot water by three methods: first method at 90 °C for 20 min, second method at 50 °C for 20 min and third method washing of other samples with aqueous solution containing 1 g/L sodium carbonate (Na_2CO_3) at 50 °C for 20 min. Using a material to liquor ratio 1:30. After the desired duration of treatment, the samples were thoroughly washed with water and dried to a constant weight (W2). The percent size removal was calculated as follows:

$$\text{The percent size removal}\,(\%) = \left[\frac{W1 - W2}{W1 - W0}\right] \times 100.$$

Residual size can be calculated as follows:

$$\text{Residual size}\,(\%) = \left[\frac{W1 - W0}{W0}\right] \times 100$$

where $W0$, $W1$ and $W2$ are the weights of samples before sizing, weights of samples after sizing and weights of samples after desizing then drying.

2.2.6. Finishing

100% cotton and 50/50% cotton/PET fabric samples were padded in a solution containing the polyblend, CMC or CMC/PVA, 50 g/L, DMDHEU, 50 g/L and magnesium chloride (5 g/L) to a wet pick up of ca. 80%, drying was achieved at 100 °C/5 min followed by curing at 160 °C/3 min. Finishing formulations used were detailed in the text. Finished fabric samples were then after-washed at 50 °C/15 min in presence of nonionic wetting agent (2 g/L) to remove unused reactants along with soluble by-products followed by rinsing and drying before testing.

2.2.7. Post dyeing

Portions of the treated fabric and control samples were post-dyed using Basic Red 18, according to a reported method (Abo-Shosha, Ibrahim, Fahmy, & Hebeish, 1995).

2.3. Chemical analysis and testing

IR Spectroscopy was carried out using BRUKER IR Spectrometer.

Extend of grafting (i.e., grafting yield (%GY) and grafting efficiency (%GE)) was determined according to the following equations:

$$\text{GY}\,(\%) = \left[\frac{\text{Wp} - \text{Wo}}{\text{Wo}}\right] \times 100$$

$$\text{GE}\,(\%) = \left[\frac{\text{Wp} - \text{Wo}}{W1}\right] \times 100$$

where Wp, Wo are the weights of purified grafted polymer (CMC-g-PVAc) and CMC and $W1$ is the weight VAc monomer, respectively.

The extent of polymerization, expressed as percentage total conversion, %TC, was determined by assessing the unsaturation (double bonds) content before and after polymerization (Welcher, 1963). The nitrogen content was determined according to Kjeldhal method (Vogel, 1975).

Dry wrinkle recovery angle (WRA) was determined according to ASTM method D-1296-98.

The oily stain release (OSR) was assessed according to the AATCC test method 130-1993.

Carboxyl content, as meq/100 g was determined according to a reported method (Hashem, Refaie, & Hebeish, 2005).

The whiteness and yellowness index were evaluated by using Colour-Eye® 3100 spectrophotometer supplied by SDL Inter, England (Welch & Peters, 1997).

Dyeability of treated and untreated fabric samples was determined by measuring K/S values (K is the absorption coefficient, S is the scattering coefficient) at wave length of maximum absorbance for the used dyes, with Color-Eye® 3100 Spectrophotometer supplied by SDL Inter. England (Duff and Sinclair).

Tensile strength (kg) and elongation at break (%) were determined according to ASTM procedure D-2296-66T.

Wettability of finished fabric samples were tested according to AATCC test method 39-1980.

Roughness for the finished samples was measured using a Surfacoder 1700a.

3. Results and discussion

3.1. Graft polymerization of CMC with VAc

3.1.1. Tentative mechanism

Grafting of CMC with Vac in presences of $(NH_4)_2S_2O_8$, as initiator, comprises the following steps (Ibrahim, Abo-Shosha, Fahmy, El-sayed, & Hebeish, 2008):