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Crosslinking of partially carboxymethylated cotton fabric via cationization

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Abstract

A novel method for non-formaldehyde easy care finishing of cotton fabric based on ionic crosslinking has been examined. Accordingly, the cotton fabric was first partially carboxymethylated to impart to it the anionic character through its reaction with monochloroacetic acid in alkaline medium. Application of reactive cationic agent in alkaline medium affects crosslinking of the resulting anionic cotton in a second step. The reactive cationic agent used was 3-chloro-2-hydroxypropyl trimethyl ammonium chloride (Quat-188). Factors affecting the quaternization reaction of partially carboxymethylated cotton fabric (PCMC) have been studied. These factors include NaOH concentration, reaction time and temperature, quaternizing agent concentration as well as material to liquor ratio and method used for quaternization. The latter includes two methods, namely, the exhaustion method and the cold pad-batch method. Correlations between the degree of crosslinking (expressed as nitrogen and carboxyl content) of quaternized PCMC fabric and the easy care properties were also made. Easy care properties include wet and dry crease recovery angles as well as tensile strength and elongation at break. Results obtained signify that: (a) optimum conditions for cationization of PCMC fabric are obtained when the Quat-188/sodium hydroxide molar ratio is 1/2 using the cold pad-batch method for 24 h; (b) the extent of cationization reaction, expressed as percent nitrogen, increases as the carboxyl content of the PCMC fabric increases, and (c) both wet and dry crease recovery angles of PCMC samples exhibit much higher values compared with that of untreated samples while both tensile strength and elongation at break display marginal improvements. These improvements depend mainly on the degree of ionic crosslinking.

Keywords: Carboxymethylation; Cationization; Cotton; Finishing; Ionic crosslinking; Textile

1. Introduction

The driving force behind the chemical finishing of cotton during the next 10 years is anticipated to comprise several factors. Of these factors, mention is made of the following: (i) chemical finishes which maximize the added value; (ii) chemical finishes which are friendly with the environment; (iii) methods which are convenient for application, and (iv) the need for better quality and minimum use of water and energy.

Since the late 1980s there has been a steady increase in the demand for easy care, wrinkle resistant (durable press) 100% cotton apparel. Formaldehyde-based chemical finishes such as dimethylol dihydroxyethylene urea and its etherified derivative with lower formaldehyde concentrations are used to impart ease of care characteristics and durable press properties to cotton apparel. They are cost effective and efficient [1–5]. However, the free formaldehyde on the finished fabric is considered one of the major problems in easy care and durable press of cotton finishing. This is understandable given that the adverse effects of this formaldehyde range from strong irritant to cancer. In addition, washing the apparel pollutes the washing liquor. By virtue of its carcinogenic effect, the allowable formaldehyde in air should not exceed 0.1 ppm in the work place and worker health must be monitored in the textile industry when it is used. This is strictly stated in recent actions by federal regulatory agencies in most industrialized countries and in some others—a point which has renewed interest in non-formaldehyde textile finishing substances for work with cotton based textiles [6,7]. Furthermore, formaldehyde-based finishing is very energy-consuming since the curing

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operation requires temperatures as high as 160 °C [4]. Consequently, the search for non-formaldehyde durable press finishes for cotton has become of highest priority.

A variety of cellulose crosslinking agents have been investigated to provide non-formaldehyde easy care finishing, e.g. polycarboxlic acid. However, numerous disadvantages such as high cost, inadequate reactivity, fabric yellowing, excessive fabric tendering and toxicity were observed with those agents. Such disadvantages have prevented their adoption in place of the formaldehyde-based finishes now in commercial use [8–13].

In this work, we present a new approach for non-formaldehyde, easy care finishing of cotton fabric. Our new approach is based on ionic crosslinking. Accordingly, the cotton fabric is first partially carboxymethylated to impart to it an anionic character through its reaction with monochloroacetic acid in alkaline medium. Crosslinking of the resulting anionic cotton is accomplished in a second step by application of reactive cationic agent in alkaline medium. The reactive cationic agent used is 3-chloro-2-hydroxypropyl trimethyl ammonium chloride (Quat-188). Emphasis is placed on investigation into factors affecting the cationization reaction of partially carboxymethylated cotton using Quat-188. Factors studied include NaOH concentration, reaction time and temperature, Quat-188 concentration, material to liquor ratio and method used for cationization. The effect of the carboxyl content of partially carboxymethylated cotton fabric (PCMC) on the extent of cationization, expressed as N%, is also studied. Also, the researchers examined the performance of the cationized PCMC. It should be mentioned here that, in the proposed method, a new route for finishing is presented. As is evident, no formaldehyde based finishes are used, thereby reducing the waste in the discharged water. Furthermore, neither Quat-188 nor monochloroacetic acid are toxic to the workers, costumers or to the environment.

2. Experimental

2.1. Materials

2.1.1. Cotton fabric

Mill scoured and bleached cotton fabric (100%) was kindly supplied by Misr Company for Spinning and Weaving, Mehala-El-Kubra, Egypt.

2.1.2. Chemicals used

Sodium hydroxide, acetic acid, hydrochloric acid, monochloroacetic acid and sodium carbonate were of laboratory grade. The compound, 3-chloro-2-hydroxypropyl trimethyl ammonium chloride (65 wt.%) was of technical grade and was kindly supplied under the commercial name (Quat-188) by Dow Chemical Company, USA.

2.2. Carboxymethylation of cotton fabric

Cotton fabric was partially carboxymethylated by a method similar to those previously reported [14–16]. Hence, bleached cotton fabric samples were impregnated with 20 wt.% aqueous NaOH for 10 min at room temperature followed by squeezing to a wet pick up of 100%. Samples were dried at 60 °C for 5 min. Different carboxymethyl contents could be achieved by varying the concentration of the sodium salt of monochloroacidic acid. Thus, alkali-treated samples were steeped in aqueous solution of sodium salt of monochloroacetic acid (0–3 mol), for 5 min at room temperature. These samples were then squeezed to 100% wet pick up, sealed in plastic bags and heated at 80 °C for 1 h. Samples were then washed and dried at room temperature. Blanks, where the cotton samples were treated only with sodium hydroxide, were made.

2.3. Cationization of partially carboxymethylated cotton fabric

Two methods were used to cationize the partially carboxymethylated cotton fabric (PCMC), namely, the pad-batch method and the exhaustion method. The experimental procedure adopted in the pad-batch method was as follows: Quat-188 was mixed in solution with sodium hydroxide. PCMC was padded through this mix, and then batched at room temperature overnight in a plastic bag. Then, the PCMC sample was washed with cold water and 1% acetic acid, then washed several times with cold water and finally dried at ambient conditions.

In the exhaustion method, the PCMC sample was introduced into an aqueous solution containing Quat-188. A calculated amount NaOH was then added dropwise with continuous stirring. The reaction temperature was raised gradually. At the end of the reaction the sample was washed several times with cold water and acidified with 1% acetic acid. Finally, the sample was washed with cold water and dried at ambient conditions. Details of the conditions used for cationization are given in the text.

2.4. Testing and analysis

The carboxyl content of the PCMC samples was determined according to a reported method [17].

The nitrogen content of the cationized samples was determined by the Kjeldhal method [18]. Fixation percent (F%) was calculated as follows:

$$F\% = \frac{\text{Amount of nitrogen fixed (detected)}}{\text{Total amount of nitrogen of Quat-188 applied}} \times 100$$