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Pre-cationization of cotton fabrics: An effective alternative tool for activation of hydrogen peroxide bleaching process

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ABSTRACT

Hydrogen peroxide is a well-known environmentally safe bleaching agent for cotton fabric. However, bleaching of cotton based fabric with hydrogen peroxide requires alkaline medium (normally NaOH), stabilizer and either high temperatures or long dwell times. After bleaching and before dyeing, large amount of water is required for washing the residual un-decomposed hydrogen peroxide and the residual alkali. In this work, a new approach for bleaching cotton based fabric is postulated and investigated. The cotton fabric was scoured and cationized with NaOH and 3-cholor-2-hydroxy propyltrimethyl ammonium chloride (commercially known as CR-2000) either concurrent in one step process or separately in two step process. The scoured and cationized cotton fabric was then preceded for hydrogen peroxide bleaching. The cationic group on the cationized cotton fabric serves a dual function in the bleaching bath; the first is *built-in* catalyst for bleaching process and the second is powerful alkali site necessary for activation of hydrogen peroxide bleaching bath instead of NaOH. Three bleaching technique are utilized in bleaching of pre-scoured and cationized cotton fabric. These techniques are, exhaustion technique, pad-steam and cold pad-batch. The effects of cationization level, bleaching technique, bleaching parameters were systematically investigated. The fabric was monitored for strength properties, whiteness index and nitrogen content before and after the bleaching process. Results obtained show that, pre-cationization of cotton fabric provide comparable fabric whiteness in all technique investigated at much shorter reaction times and lower bleaching temperature in absence of NaOH. These results call for a breakthrough not only in bleaching of cotton based textiles but also in conventional detergent washing formulation.

1. Introduction

Industrial processes in everyday life must become environmentally safer, cost-effective and must conserve energy. This is a major goal of today's life science research. Current industrial trends place an emphasis on the manufacture of diverse product ranges with high added value at relatively small lots. Consequently, increasing concern has been expressed over how industry can adapt to this trend and still achieve energy saving. For these purposes, several approaches have been postulated in the last two decades for pretreatment and bleaching of cotton fabric. One is to combine pretreatment (or preparation) processes to save energy and chemicals. Another recent aspect is the use of bleach catalyst (BoÈsinga et al., 1999; Dannacher, 2006; Suss, 2003).

Cotton cellulose has excellent properties such as higher water absorbency and moisture, being comfortable to wear and easily to dye. For these reasons, the apparel industry is predominantly cotton based, and the share of cotton in total fibre consumption is about 50% (Karmakar, 1999).

Cotton is composed almost entirely of cellulose (90–96% based on weight of fibres). The impurities in cotton fibre range from 4% to 10%. The overall composition of raw cotton fibres depends on its type, origin, fibres maturity, weathering and agricultural conditions (Brushwood, 2003; Carr, 1995; Karmakar, 1999; Segal & Wakelyn, 1988). The impurities include protein (1.0–2.1%), wax (0.4–1.7%), ash (inorganic salts) (0.7–1.8%), pectin (0.4–1.9%) and others (resins, pigments, hemi-cellulose) (1.5–2.5%) (Brushwood, 2003; Karmakar, 1999; Segal & Wakelyn, 1988). The yellowish or brown coloration of the cotton fibre is related to the protoplasmic residues of protein and the flavones pigments of cotton flowers (Karmakar, 1999; Segal & Wakelyn, 1988).

With the exception of natural coloring matters that may be removed by bleaching using certain oxidants, many other impurities are removed by alkali treatment in scouring stage. The latter in common practice involves boiling the cotton in sodium hydroxide (2–5%) for 1 h (Lewin & Sello, 1984; Segal & Wakelyn, 1988).

Hydrogen peroxide is a well-known environmentally safe bleaching agent for cotton fabrics. However, bleaching of cotton based fabrics with hydrogen peroxide requires alkaline medium

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(normally NaOH), stabilizer and either high temperatures or long dwell times. After bleaching and before dyeing, large amount of water is required for washing the residual un-decomposed hydrogen peroxide and the residual alkali (Brooks & Moore, 2000; Dannacher & Schlenker, 1996; Lewin & Sello, 1984; Schulz, 1990; Spiro & Griffith, 1997; Zeronian & Inglesby, 1995).

It is thus desirable to use bleaching systems that operate well at lower temperatures, shorter reaction times and/or using lower chemical charges than current, without causing unacceptable damage to textile fibers. This, indeed, stimulates the present work which is undertaken with a view to development a new approach for bleaching cotton based fabrics with hydrogen peroxide.

Desirable properties are imparted to cellulosic textile fabrics when treated with 3-chloro-2-hydroxypropyl trimethyl ammonium chloride, render them cationic in nature (Hashem, 2006; Hauser, 2000; Hauser & Tabba, 2001, 2002). The quaternary ammonium group-+$N(CH_3)_3$ has a very high positive charge and can thereby lead to the formation of ionic bonds (salt linkages) with negatively charged anionic groups, such as those found in wide array of anionic dye classes or carboxyl containing compounds. The former impart no-salt dyeing properties to cotton fabric (Hashem, 2006; Hauser, 2000; Hauser & Tabba, 2001, 2002) whereas, the latter impart ionic crosslinking for cotton fabric renders it wrinkle recovery (Hashem, Hauser, & Smith, 2003a; Hashem, Smith, & Hauser, 2003b). Moreover, the presence of cationized groups in the cellulose imparts also antimicrobial properties to cotton fabric (Seong & KO, 1998).

In this work, a new approach for bleaching of cotton based fabric is postulated and investigated. Accordingly, cotton fabric was scoured and cationized with NaOH along with 3-cholor-2-hydroxy propyltrimethyl ammonium chloride (CR-2000) either concurrent in one step process or separately in two step processes then proceed for hydrogen peroxide bleaching. The cationic groups on the cationized cotton fabric serves a dual function in the bleaching bath; the first is *built-in* catalyst for bleaching process and the second is powerful alkali site necessary for activation of hydrogen peroxide bleaching bath instead of NaOH.

The effects of cationization level, bleaching technique, bleaching parameters were systematically investigated. The fabric was monitored for strength properties, whiteness index and nitrogen content before and after the bleaching process.

2. Experimental

2.1. Cotton fabric and chemicals

Greige 100% woven cotton fabric was supplied by Misr Company for Spinning and Weaving, Mehala El-Kura, Egypt. The fabric has the following specification: plain weave, warp 36 yarn/cm, weft 30 yarn/cm, fabric weight, 150 g/m^2. Chemical analysis carried out on the greige fabric showed that the fabric warps were sized with starch-based sizing agent.

Sodium hydroxide, sodium carbonate, sodium chloride, ammonium persulphate, acetic acid, hydrochloric acid, were of laboratory grade chemicals. 3-Chloro-2-hydroxypropyl trimethyl ammonium chloride (CHTAC) (69%) of technical grade chemicals was kindly supplied under the commercial name CR-2000 by Dow Chemical Company, USA. Egyptol® (non-ionic wetting agent based on ethylene oxide condensate) and Espycon® (anionic wetting) agent were supplied from Starch and Yeast Co., Alexandria, Egypt. Hydrogen peroxide (50 wt.%), sodium silicate solution 48° Be′, and amylase enzyme were of technical grade chemicals.

2.2. Desizing

Greige cotton fabrics (100 g) were desized by padding the fabric in solution containing diastase enzyme (2 g/l), sodium chloride (1 g/l), acetic acid (1 g/l), Egyptol® (4 g/l) and Espycon® (2 g/l). The sample was then squeezed to a wet pick up of 100% and stored at room temperature for 8 h. The sample was washed several times with hot water then with cold water and dried at ambient conditions.

2.3. Scouring

Scouring of the desized cotton fabrics were carried out using impregnation technique, the experimental technique was adapted as follows: 100 g of desized cotton fabric were treated with an aqueous solution containing NaOH (6 g/l), Egyptol® (2 g/l) and Espycon® (1 g/l) using material to liquor ratio (LR) 1:30 at 95 °C for 30 min. The samples were washed several times with boiling water then washed with cold water and finally dried at ambient conditions.

2.4. Cationization of scoured cotton fabric

Scoured cotton fabrics were cationized using the cold pad-batch technique according to previous reported method (Hauser, 2000; Hauser & Tabba, 2001, 2002). Experimental procedure adopted as follows, 100 g/l, CR-2000 was mixed with 40 g/l, sodium hydroxide then the solution was completed to 1 L. Scoured cotton fabric was padded through this mix and squeezed to wet pick up of 100%, then batched in a plastic bag at room temperature overnight. The fabrics were washed with cold water and 1% acetic acid, then washed several times with cold water and finally dried at ambient conditions.

2.5. One step process for scouring and cationization

One step process for scouring and cationization of cotton fabric was carried out as described elsewhere (Hashem, 2006). The experimental technique was adopted as follows:

Desized cotton fabric was padded in an aqueous solution containing (50–200 g/l) CR-2000 and (25–75 g/l) NaOH. The fabric was then squeezed to a wet pick up of 100%, and then batched at room temperature overnight in a plastic bag. At the end, the fabrics were washed with boiling water then acidified with 1% w/w aqueous acetic acid. Finally, washed several times with cold water and dried under ambient conditions.

2.6. Bleaching

Three techniques were investigated to bleach scoured and cationized cotton fabric, namely, exhaustion, pad-steam and cold pad-batch. In the exhaustion method, scoured cotton fabrics were treated with an aqueous solution containing H_2O_2, (6 g/l), sodium silicate, (0–2 g/l), NaOH, (0–2 g/l). A material to liquor ratio of 1:30 was used and the bleaching process was carried out at (30–90 °C) for (15–90 min). The fabric was then washed several times with boiling water, then with cold water and finally dried at ambient conditions.

In pad-steam method, the fabric samples were padded in a solution containing H_2O_2 (15 g/l), sodium silicate (0–8 g/l) NaOH, (0–2 g/l). The fabric was then squeezed to a wet pick up of 100% and stored in a sealed stainless steel cup at 100 °C for 45 min. After bleaching, the sample was washed several times with hot water, then with cold water and finally dried at ambient conditions.

In cold pad-batch method, the sample was treated similar to that obeyed in pad-steam method except that the fabric was batched overnight at room temperature in polyethylene bag.

Scoured uncationized cotton fabrics were bleached similarly with each technique for comparison.