Carbohydrate Polymers 94 (2013) 612–618

Contents lists available at SciVerse ScienceDirect

Carbohydrate Polymers

journal homepage: www.elsevier.com/locate/carbpol

A smart approach to add antibacterial functionality to cellulosic pigment prints

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ARTICLE INFO

Article history:
Received 28 November 2012
Received in revised form
16 December 2012
Accepted 17 January 2013
Available online 23 January 2013

Keywords:
Cellulosic substrates
Chitosan
Ag-NP's/PVP colloid
Triclosan
Choline chloride
Microwave
Pigment printing
Antibacterial functionality

ABSTRACT

This study was devoted to enhancing the antibacterial functionality of pigment printed cotton, linen and viscose fabrics. Ag-NP's/PVP colloid, triclosan derivatives, chitosan or choline chloride was successfully incorporated into the pigment paste followed by printing and microwave curing to impart antibacterial activity to the cellulosic prints. Results obtained demonstrate that the modified pigment prints exhibit a remarkable antibacterial activity against the G+ve (*Staphylococcus aureus*) and G−ve (*Escherichia coli*) bacteria with a noticeable durability after 20 washing cycles without adversely affecting the printing and softness properties. The extent of printability and functionality of the nominated substrates are significantly governed by the type of: bio-active ingredient, binder, pigment and substrate. TEM, SEM and EDX analysis confirmed the formation of Ag-NP's/PVP colloid, of particle size range 7–14 nm, deposition of cross-linked-binder film onto the modified pigment prints, and the existence of elementary Ag and Si loaded onto fabrics surface, respectively.

1. Introduction

Cellulosic fabrics form the most commonly printed substrates. The vast majority of printed fabrics have been printed with pigment colorants, more than 50% of all prints, most probably due to simplicity, applicability to most of textile substrates, versatility, and quality of prints as well as the ability to avoid any after washing steps.

Successful pigment printing formulation comprises: pigment dispersion, thickening agent for giving the required rheology, as well as, the binding and cross-linking agents to fix the pigment colorant, which has no affinity for the textile fibers, onto the substrate by adhesion during the fixation step (Bahmani, East, & Holme, 2000; El-Molla & Schneider, 2006; Giesen & Eisenlohr, 1994; Gutjahr & Koch, 2003, Chap. 5; Ibrahim, El-Zairy, Zaky, & Borham, 2005; Iqbal, Mughal, Sohail, Moig, & Ahmed, 2012; Neral, Sostar-Turk, & Voncina, 2006; Schwindt and Fanlhaber, 1984; Waris, Iqbal, Aleem, & Ali, 2009; Yaman, Ozdogan, & Seventekin, 2012). In addition, a need remains for improving the performance properties of pigment prints as well as minimizing the environmental impacts of the pigment printing process.

On the other hand, cellulosic fabrics have been recognized as proper media to support the growth of microorganisms, e.g. bacteria, fungi, etc. The growth of microorganisms is accompanied by the generation of unpleasant odor, stains, discoloration, and partial deterioration along with increased likelihood of contamination (Gao & Cranston, 2008; Ibrahim, Eid, & El-Batel, 2012). So, it is highly desirable to stop or minimize the microbial growth on the cellulosic substrates without adversely affecting their quality and appearance taking in consideration both the consumer demands, i.e. the wearer, for hygienic clothing and active wear as well as the environmental concerns. Recently many approaches have been developed to confer antimicrobial textiles using various bioactive agents to effectively kill and/or control bacterial growth and to sustain durability such as: metal salts (Gao & Cranston, 2008; Ibrahim, Abo-Shosha, Gaffar, Elshafei, & Abdel-Fatah, 2006; Ibrahim, Eid, Hashem, Refai, & El-Hossamy, 2010; Ibrahim, Eid, Youssef, El-Sayed, & Salah, 2012; Ibrahim, El-Gamal, Gouda, & Mahrous, 2010; Ibrahim, Mahrous, El-Gamal, Gouda, & Husseiny, 2010), metal nanoparticles (Dastijerdi & Montazer, 2010; Gowri et al., 2010; Ibrahim, Amr, Eid, Mohamed, & Fahmy, 2012; Ibrahim, Eid, & El-Batel, 2012; Ibrahim, Refaie, & Ahmed, 2010; Mahapatra & Karak, 2008); re-generable N-halamine compounds (Gouda & Ibrahim, 2008; Ibrahim, Aly, & Gouda, 2008; Lui & Sun, 2006; Qiam & Sun, 2004), quaternary ammonium compounds (Gao & Cranston, 2008; Son, Kaim, Ravikumar, & Lee, 2006), halogenated phenols, e.g. triclosan (Hashem, Ibrahim, El-Sayed, El-Husseiny, & Elanany, 2009; Ibrahim, Hashem, El-Sayed,

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http://dx.doi.org/10.1016/j.carbpol.2013.01.040

El-Husseiny, & Elanany, 2010; Orhan, Kut, & Gunesoglu, 2009), chitosan (Lim & Hudson, 2003; Shin, Yoo, & Jang, 2001), Neem oil (Ibrahim, Eid, & El-Zariy, 2011; Joshi, Ali, & Rajendren, 2007) and immobilized enzymes (Ibrahim, Gouda, El-Shafei, & Abdel-Fattah, 2007).

Therefore, particular attention in this article has been paid on demonstrating the feasibility of the combined pigment printing and antibacterial finishing of cellulosic fabrics taking in consideration the environmental concerns.

2. Experimental

2.1. Materials

Plain weave 100% mill-scoured and bleached cotton (120 g/m^2), viscose (110 g/m^2) and linen (207 g/m^2) fabrics were used in this work.

Invansan® (Triclosan derivative, Huntsman, USA), Ruco®-BAC MED (nonionic antibacterial agent based on diphenyl alkane derivatives of triclosan, Rudolf chemie), chitosan (degree of deacetylation of >85%, Sigma), GBresin® CPN (based on hydroxymethylated 4,5dihydroxyethylene urea, GB Chem, BASF, Egypt), Durex® Silicone-1020 (based on modified polysiloxane microemulsion, Texchem, Egypt), Printofix® Binder MTB-01 liquid (acrylate based copolymer, anionic clariant), GBinder® FMD (based on polyacrylate, anionic, GB Chem, BASF, Egypt), Printofix® Thickener 160 EG liquid (synthetic thickening agent based on ammonium polyacrylate, Clariant), Printofix® Red H3BD pigment (Clariant), Imperon® Royal Blue SP pigment (DyStar), Unisperse® Yellow MR pigment (Ciba), were of commercial grade.

All other chemicals used during this study such as $AgNO_3$ (sigma), polyvinyl pyrolidone (PVP-40,000 Dalton, Merck) and ethylene glycol (Aldrich), ammonium persulphate $(NH_4)_2S_2O_8$ and choline chloride (Aldrich) were of laboratory reagent grade.

Fig. 1 shows the chemical structure of cellulose and active ingredients.

2.2. Methods

2.2.1. Synthesis of Ag-NP's/PVP colloid

The colloid of Ag-NP's/PVP was prepared in a manner analogous to the procedures proposed by Carotenuto, Pepe, and Nicolais (2000). PVP (1.728 g), as a protective agent, was dissolved in ethylene glycol (130 ml), as a solvent and reducing agent for $AgNO_3$ at room temperature, and to this solution, the required amount of $AgNO_3$ (86.9 mg) was added. The solution was stirred at room temperature until complete dissolution of the $AgNO_3$ and then kept at this temperature for 24 h without further stirring. The pH of the reaction solution was kept at pH 8.

2.2.2. Pigment printing

Guide formulation for aqueous pigment printing using flat screen technique follows:

Constituent	g/kg paste
Pigment	20
Thickener	20
Binder	100
Cross-linker	20
Softener	10
NH_4-persulfate	2
Bio-active material	20
Acetic acid	1
Water	807
Total	1000

Printed fabric samples were then simultaneously dried and fixed in a commercial microwave oven at output power of 386 W/5 min.

2.3. Measurements

Nitrogen content (%N) was determined according to the Kjeldahl method.

Metal content of the treated samples was quantitatively determined by using Flame Atomic Absorption Spectrophotometer GBC-Avanta, Australia

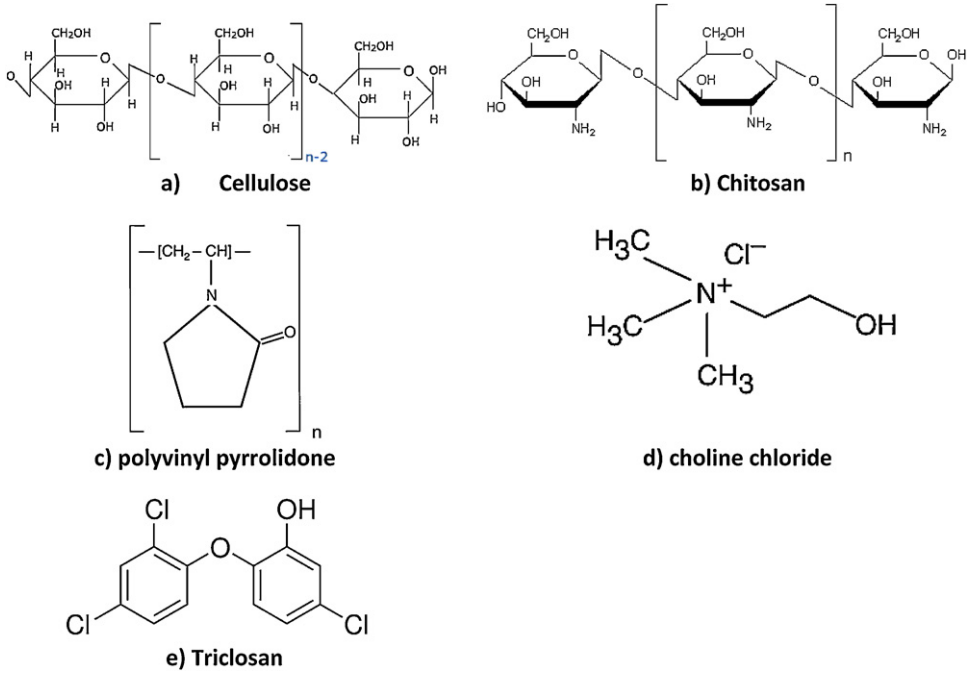

Fig. 1. Chamical structures of cellulose (a), chitosan (b), polyvinyl pyrrolidone (c), choline chloride (d), and triclosan (e).