Carbohydrate Polymers 92 (2013) 1539–1545

Contents lists available at SciVerse ScienceDirect

Carbohydrate Polymers

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

Enhancing some functional properties of viscose fabric

H.M. Fahmy[a,*], R.A.A. Eid[b], S.S. Hashem[b], A. Amr[a]

[a] Textile Research Division, National Research Center, Dokki, Cairo, Egypt
[b] Faculty of Home Economic, Menoufia University, Egypt

ARTICLE INFO

Article history:
Received 12 October 2012
Received in revised form 31 October 2012
Accepted 3 November 2012
Available online 13 November 2012

Keywords:
Poly (N-vinyl-2-pyrrolidone)
Viscose fabric
Tinosan® CEL
Nano-particles
Antibacterial properties
UV protection
Self cleaning

ABSTRACT

To enhance the functional properties of viscose fabrics, Tinosan® CEL (TC), Ag, and TiO_2 nano-particles were incorporated as functional additives in different easy care finishing formulations alone and in admixtures. Results indicated that padding viscose fabrics in finishing bath containing 10 g/l TC and 60 g/l dimethyloldihydroxyethylene urea (DMDHEU) enhances some performance as well as antibacterial properties of the treated fabrics. Moreover, incorporation of Ag or TiO_2 nano-particles in the DMDHEU or DMDHEU/TC finishing baths enhances the functional properties of the treated samples such as antibacterial properties, UV-blocking properties, and/or self cleaning performance. Incorporation of poly (N-vinyl-2-pyrrolidone) in the aforementioned finishing formulations enhances these functional properties along with durability to wash. On the other hand, incorporation of Silicon®-SLH softener in finishing baths along with TC affects the performance and antibacterial properties of the treated fabrics.

1. Introduction

Cellulosic textiles such as cotton and viscose are vulnerable to the microbial attack during use and storage due to their porous hydrophilic structure that retains water, oxygen and nutrients (Abo-Shosha, Hashem, El-Hosamy, & El-Nagar, 2007; Hou, Zhou, & Wang, 2009; Orhan, Kut, & Gunesoglu, 2009). Growing the microbes on textiles causes bad effects for the wearer as well as the textile itself. Such effects include unpleasant odor, stains and discoloration in the fabric, and a reduction in the fabric mechanical strength. For the wearer it causes skin irritation and leads to cross infections (Abo-Shosha et al., 2007; Orhan et al., 2009). The detrimental effects can be controlled by durable antimicrobial finishing of the textile using broad-spectrum biocides. Triclosan (2,4,4′-trichloro-2′-hydroxydiphenyl ether) is important as a textile antibacterial finish. It inhibits the microbial growth by blocking lipid biosynthesis (Gao & Cranston, 2009; Purwar & Joshi, 2004). During fabric use, the agent migrates to the surfaces of the treated textiles at a slow sustained rate to provide antimicrobial efficacy. To achieve a more durable finishing, Triclosan has been inserted into the hydrophobic cavity of β-cyclodextrins to form an inclusion complex which was then embedded in a polymer film or fiber, or encapsulated in microspheres which were subsequently attached to viscose (Purwar & Joshi, 2004). Antibacterial/easy care finishing of knitted cotton fabric is investigated by Abo-Shosha et al. (2007) by incorporation of a Triclosan in the easy care finishing formulation. Durable antibacterial finishing of cotton/polyester fabrics was performed by Ibrahim et al. using Triclosan (Ibrahim, Hashem, El-Sayed, El-Husseiny, & El-Enany, 2010). Besides, many heavy metals are toxic to microbes at very low concentrations either in the free state or in compounds (Purwar & Joshi, 2004). Textiles loaded with silver or titanium dioxide nano-particles exhibit antimicrobial properties (Ibrahim, Eid, Hashem, Refai, & El-Hossamy, 2010). Moreover, poly (N-vinyl-2-pyrrolidone) (PVP) is a synthetic, nontoxic, water-soluble polymer commonly used in a wide range of applications including several pharmaceutical applications. PVP polymers are film formers, protective colloid and suspending agents, dye-receptive agents, binders, stabilizers, detoxicants, and complexing agents (Barabas, 1990). PVP can be crosslinked by heating in air at 150 °C (Blecher, Lorenz, Lowd, Wood, & Wyman, 1980), radiation (Chapiro & Legris, 1986) and potassium persulfate (Can, Kirci, Kavlak, & Uner, 2003). Fahmy et al. crosslinked cotton fabrics with PVP thermally (Fahmy, Abo-Shosha, & Ibrahim, 2009).

On the other hand, the ultraviolet radiation (UVR) is a segment of the electromagnetic spectrum with a wavelength ranging from 100 to 400 nm. The UVR wavelength ranging from 290 to 320 nm is most responsible for the development of skin cancers (Chen, Wang, & Yeh, 2010; Ibrahim, Refaie, & Ahmed, 2010).

Keeping in mind this background, the present work is undertaken with the view to establish the proper conditions to impart easy care finished viscose fabric antibacterial and ultraviolet protection properties as well as self cleaning performance.

* Corresponding author.
E-mail address: aukal34@yahoo.com (H.M. Fahmy).

0144-8617/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.carbpol.2012.11.008

2. Experimental

2.1. Materials

2.1.1. Fabrics

The fabric used throughout this work was 100% viscose fabric of weight 185 g/m^2 and thickness 0.55 mm.

2.1.2. Chemicals

Poly (N-vinyl-2-pyrrolidone) (PVP) of molecular weights 10,000 Da (Sigma–Aldrich) and titanium tetraisopropoxide (Merck) were used. Triclosan in the form of a commercial product namely Tinosan® CEL (TC), a mixture of 2,4,4′-trichloro-2′-hydroxydiphenylether and polymeric encapsulating material, was used as an antibacterial agent and kindly supplied by Ciba, Switzerland. Arkofix® NG, aqueous solution of dimethyloldihydroxyethylene urea (DMDHEU), kindly supplied by Clariant, Egypt. The commercial textile softeners (TSs) namely: Basosoft® SWK (weakly cationic mixture of a fatty acid condensation product and polyethylene wax, supplied by BASF), Leomin® NI-ET (nonionic, hydrophilic, and supplied by Clariant) and Silicon®-SLH (micro emulsion silicon softener) (SME), supplied by Texchem Egypt CO., LTD, were used. Egyptol®, non-ionic wetting agent, supplied by the Egyptian Company for Starch and Yeast and Detergents, Egypt, was used. Sodium hydroxide, trisodium citrate, silver nitrate, acetic acid, sodium carbonate, boric acid, hydrochloric acid, sulfuric acid, ammonium chloride, magnesium chloride, zinc sulfate, copper sulfate, potassium sulfate, Methylene Blue, as a basic dye, were of laboratory grade chemicals.

2.2. Methods

2.2.1. Titanium dioxide sol–gel preparation

Titanium dioxide nano-particles (TiO_2-NPs) were prepared as previously reported using titanium tetraisopropoxide precursor with 2-propanol and nitric acid (Bozzi, Yuranova, & Kiwi, 2005).

2.2.2. Silver nano-particles preparation

Silver nano-particles (Ag-NPs) were prepared using trisodium-citrate as a reductant as reported elsewhere (Sileikaite, Prosycevas, Puiso, Juraitis, & Guobiene, 2006).

2.3. Fabric treatments

2.3.1. Easy care finishing in presence of Tinosan® CEL

Viscose fabric strips (30 cm × 30 cm) were padded twice, at wet pick-up 85%, in different finishing formulations containing DMDHEU/NPs, DMDHEU/NPs/PVP, DMDHEU/TC, DMDHEU/TC/NPs, DMDHEU/TC/NPs/PVP or DMDHEU/TC/TSs (using ammonium chloride, magnesium chloride or zinc sulfate as a catalysts). The padded fabrics were dried at 85 °C for 5 min followed by curing in Wenner Mathis AGCH-8155 oven at specific temperature and intervals of time. The finished fabrics were then washed under occasional stirring (at 50 °C for 10 min), thoroughly rinsed and finally dried for testing.

2.4. Testing and analysis

- Nitrogen content (%N) was determined according to Kjeldhal method (Vogel, 1975).
- Wrinkle Recovery Angle (WRA) was determined according to ASTM method D-1296-98.
- Tensile strength (TS) was tested in the warp direction according to ASTM procedure D-2256-98.
- Wettability (W) was carried out according to AATCC Test Method 39-1980.
- Whiteness index (WI) was evaluated by using Color-Eye® 3100 spectrophotometer supplied by SDL Inter, England, according to the Standard Test Method ASTM E313.
- Surface roughness (SR) was measured according to JIS 94 Standard, by Surface Roughness Measuring Instrument, SE 1700α.
- The color strength of the of the dyed samples, expressed as *K*/*S* value, was measured on Optimacth 3100 and the values were automatically calculated from reflectance data by use of Kubelka–Munk equation (Judd & Wyszecks, 1975).

$$K/S = \frac{(1-R)^2}{2R}$$

where R is the reflectance of the dyed fabric at the wavelength of maximum absorption and K/S is the ratio of the absorption coefficient (K) to the scattering coefficient (S).

- Ultraviolet-protection factor (UPF) values were calculated according to the Australian/New Zealand standard (AS/NZS 4399-1996) with a UV-Shimadzu 3101 PC spectrophotometer. According to the Australian classification scheme, fabrics can be rated as providing good protection, very good protection, and excellent protection if their UPF values are 15–24, 25–39, and greater than 40, respectively.
- Scanning electron microscope (SEM) images of the treated and untreated fabric samples were obtained Using SEM Model Quanta 250 FEG (Field Emission Gun) attached with EDX Unit (Energy Dispersive X-ray Analyses), with accelerating voltage 30 kV, magnification 14× up to 1,000,000 and resolution for Gun.1n), FEI company, Netherlands.
- The morphology and particles size of Ag-NP's and TiO_2-NP's were obtained by transmission electron microscope (TEM) using a JEOL, JEM 2100 F electron microscope at 200 kV.
- Antimicrobial activity of control and finished viscose fabrics were tested, expressed in the inhibition zone (IZ) per millimeters, according to the disc diffusion method, AATCC Test Method 147-2004. The antibacterial activities of the untreated blank as well as finished fabrics were tested against the following bacteria:
  (1) Gram-positive bacteria: *Staphylococcus aureus (SA)*.
  (2) Gram-negative bacteria: *Escherichia coli (EC)*.
- Durability to wash was assessed by subjecting the fabric to 1, 15 and 25 laundering cycles. Each laundering cycle consists of washing (10 min at 50 °C using 2 g/l nonionic surfactant followed by rinsing and air drying at ambient conditions.
- The self-cleaning action of the TiO_2-loaded substrates was assessed as described elsewhere (Ibrahim, Refaie, et al., 2010).

3. Results and discussion

Tinosan® CEL (TC), silver or titanium dioxide nano-particles and some textile softeners were utilized, individually or in combinations, to functionalize viscose fabric. Factors affecting the performance and functional properties of viscose fabric were investigated. Results obtained along with appropriate discussion follow.

3.1. Imparting functional properties to viscose fabric

3.1.1. Tinosan® CEL

3.1.1.1. Tinosan® CEL concentration. Fig. 1 shows the antibacterial activities of viscose fabric samples treated with different concentrations of Tinosan® CEL in presence of 60 g/l of DMDHEU. It is obvious that increasing the Tinosan® CEL concentration from 0 to 15 g/l, brings about an increase in the inhibition zone, against