Simultaneous pigment printing and antibacterial functionalization of wool and wool/polyester blend fabrics

H. M. Khalil
Faculty of Applied Arts, Printing, Dyeing and Finishing Department, Helwan University, Cairo, Egypt.
bopart_star @ yahoo.co

Abstract:
In this study, PEG-600 and triclosan derivative (Ruco® BAC MED) were used as bioactive agents in pigment printing formulations [pigment color (20 g/kg); DAICO® Thick. 160 (20 g/kg); Printofix® Binder MTB-01 (100 g/kg); Knittex® FEL crosslinking agent (10 g/kg); ammonium persulfate $(NH_4)_2S_2O_8$ (2 g/kg)]. The effects of printing and microwave fixation at 1300W/4 min on simultaneous functionalization and coloration of wool and wool/polyester blended fabrics were investigated. The present results showed that the antibacterial properties and the depth of shad of the resulted functionalized pigment prints are ingredient determines by the bioactive agent's nature and the type of substrate and decrease in the following order: PEG-600 (20g/Kg) > Ruco® BAC MED (20g/Kg) >> none and polyester/wool > wool.

Keywords:
Pigment printing, antibacterial finishing, wool and wool/polyester blended textiles.

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1- Introduction

Natural textiles, in particular, provide an ideal environment for the proliferation of microorganisms (fungi, bacteria, algae and yeast dust mites). Microorganisms growing on fabrics have a number of undesirable consequences depending on the wearer, as infectious disease by germs that cause disease, unappealing body odour, as well as on the fabric itself, like splotches, discolouration and reduction of mechanical strength; and hence, it is critical to use antimicrobial agents to prevent and/or reduce microbe growth on textiles when in use and storage (1-4). Antimicrobial agents work in a variety of ways to stop germs from growing. In general, it targets the microbe's cell wall, inhibits cell wall synthases, and changes the permeability of the membrane that surrounds the cytoplasm. Moreover, changes the chemical and physical states of nucleic acid and proteins production, as well as inhibiting enzyme activity (3,5-7).

Many efforts have recently been made to add textiles' functionality by employing antimicrobial agents, for example quaternary ammonium salts, nanomaterials, neem oil, clove oil, triclosan, bioactive agents and chitosan to destroy and/or control growth of bacteria (7-11).

The overall aim of this study is to provide antimicrobial properties and improve printability of pigment of wool and wool/polyester blend fabrics in a single step by incorporating bio-active agents such as PEG-600 and Ruco® BAC MED as antimicrobial agents into pigment paste compositions, Printing and microwave fixation follow.

2. Experimental

2.1. Materials

Mill-scoured, semi-bleached wool fabric (220g/m^2) and a polyester/wool (50/50, 230g/m^2) blend were used in this study.

Printofix® Binder MTB-01 liquid (binding agent based on acrylate copolymer, Clariant), DAICO® Thick. 160 (synthetic thickener based on polyacrylate, Daico, Egypt), Knittex® FEL crosslinking agent (reactant crosslinking agent based on a modified dimethylol dihydroxy ethyleneurea, Huntsman), Ruco® BAC MED (nonionic antibacterial finishing agent, based on diphenyl alkane derivative of triclosan- Rudolf Chemie), Pigment Red 146 and Pigment Blue 153 (Daico, Egypt) were of commercial grade.

All other chemicals used in this study such as ammonium persulphate $[(NH_4)_2S_2O_8]$ and polyethylene glycol (PEG-600) were of laboratory regent grade.

2. 2. Methods

2.2.1. Pigment printing and antibacterial finishing in a single step

The wool and polyester/wool fabric samples were pigment printing and antibacterial finishing using the flat screen technique and the following print paste formulations:

Components	g/kg paste
Pigment color	20g
Printofix® Binder MTB-01	100g
DAICO® Thick. 160	20g
Knittex® FEL crosslinking agent	10g
Ammonium persulphate $(NH_4)_2S_2O_8$	2g
Functional additives:	

PEG-600	20g
Ruco® BAC MED	20g
H_2O	X g
Total	1000

Printed fabric samples were then simultaneously dried and fixed in a commercial microwave oven at output of 1300W/4 min.

2.2.2. Testing

The depth of the obtained disperse prints, expressed as K/S, was measured at the wavelength of the maximum absorbance using an automatic-filter spectrophotometer, and calculated by the Kubelka Munk equation (12):

$$K/S = (1-R)^2 / 2R$$

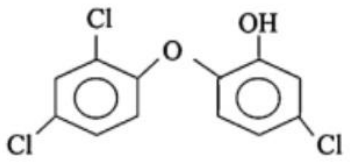
where K, S, and R are the absorption coefficient, the scattering sufficient and the reflectance at the wavelength of maximum absorbance of the used dye respectively.

Fastness properties to washing, rubbing, perspiration and light of printed fabric samples were evaluated according to AATCC test methods: (61-1972), (8-1972), (15-1973) and (16A-1972) respectively.

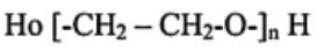
Antibacterial efficacy of the functionalized pigment prints against G+ve bacterial (*S.aureus*) and G-ve bacteria (*E.coli*) was evaluated qualitatively according to AATCC Test Method (147-1988), and expressed as zone of growth inhibition (ZI, mm).

3. Results

In order to improve the antibacterial activity of wool and wool/polyester pigment prints, the current study investigated the technical viability of performing simultaneous functionalization and pigment coloration in a one step by individually incorporating appropriate active ingredients, namely PEG-600 and Ruco® BAC MED (triclosan derivative) (Fig.1) into solvent–free pigment formulations.



a) Triclosan (Ruco® BAC MED)



b) PEG-600

Fig. 1. Chemical structures of chemicals: (a) Triclosan (Ruco® BAC MED) and (d) PEG- 600

3.1. PEG-600

Table 1 shows the effect of introducing PEG-600 into printing pastes on pigment printability and antimicrobial functionality of the selected wool and wool/polyester blended fabrics. For a specific set of simultaneous finishing and pigment printing conditions, It is obvious that: i) using PEG-600 (20g/kg) in the printing formulations as a bio-active agent and as an eco friendly substitute for urea results in a considerable increase in the K/S of prints obtained as well as a development in their fastness properties, ii) this major advancement in printing characteristics is due to PEG-600's capacity to: facilitates and enhance the degree of transmission of pigment from the paste to the surface of fiber; take part in side interactions with the used Printofix® Binder MTB-01 binding agent and/or Knittex® FEL crosslinking agents, thus also increasing the degree of crosslinking and polymerization; enhance location, extent of distribution, also adherence and loading of binder film onto the surface of the fabric, thus also providing more accessible of higher K/S and superior fastness properties, locations for further entrapment and fixing of additional particles of pigment within/onto the fiber/fabric matrix iii) distinctions in printing properties are expected to be influenced by the nature of the substrate, wool/polyester > wool, and the pigment colorants previously mentioned, iv) during the microwave fixation step, PEG-600 moieties are fixed onto/within the printed substrates results in a significant increase in their antimicrobial efficiency, v) the antimicrobial effect imparted is in decreasing order: wool/polyester > wool, and pigment Red146 > pigment Blue 153, while all other variables remain constant, vi) the antimicrobial properties of pigment prints PEG-loaded is most likely due to a chemical-physico phenomenon and its capacity to disrupt cellular membranes balance by having caused double hydrophilic-hydrophobic conduct, and vii) the efficiency against *S.* aureus (G+ve) and *E.*coli (G-ve) follows in descending order: G+ve > G-ve (2, 13, 14).

Table 1. Effect of inclusion of PEG-600 into the pigment printing formulations on the printing properties and antimicrobial properties of pigment prints different colors

Pigment Colors	Substrate		K\S	Incr. in K/S (%)	WF		RF		PF				LF	Antimicrobial Activity (zone mm)	
					Alt	C	Dry	Wet	Acidic		Alkaline			G +ve	G −ve
									Alt	C	Alt	C			
Pigment Red 146	W	UT	11.18	84.34	3	3-4	4	4	4	3-4	3	3	2-3	0.0	0.0
		T	20.61		4-5	4	4-5	4	4	4	3-4	4	4	21.0	20.0
	W/PET	UT	15.34	36.17	3	3	3	2-3	4	4	2-3	4	4	0.0	0.0
		T	20.89		4-5	4-5	4-5	4-5	5	5	4-5	5	4-5	22..0	20.5
Pigment Blue 15:3	W	UT	10.92	26.19	3	2-3	4-5	4	4-5	2-3	4	3	2-3	0.0	0.0
		T	13.78		4	4	4-5	4-5	4-5	4	4-5	3-4	4-5	20.0	17.0
	W/PET	UT	13.03	23.17	2-3	4-5	4	3	3	4	4	4-5	2-3	0.0	0.0
		T	16.05		4	4-5	4-5	4	4	4-5	4-5	5	4-5	21.0	19.0

- Pigment printing conditions: Pigment color (20 g/kg); DAICO-Thick.1600 (20 g/kg); Printofix® Binder MTB-01 (100 g/kg); Knittex® FEL crosslinking agent (10 g/kg); ammonium persulfate (2 g/kg); PEG-600 (20 g/kg).
- Microwave fixation at 1300W/4min. followed by after –washing at 40˚C for 15 min in presence of (2 g/L) nonionic wetting agent.
- K/S: color depth; WF: wash fastness; Alt: alteration; C: staining on cotton; RF: rubbing fastness; PF: perspiration fastness; LF: light fastness; ZI: zone of inhibition; W: wool; W/ PET: wool/ polyester blend; UT: untreated; T: Pigment printed with PEG-600.

3.2. Ruco®-BAC MED (Triclosan derivative)

The data in Table 2 show that the incorporation of the triclosan derivative Ruco®-BAC MED, along with other ingredients, into pigment printing pastes, screen printing and microwave curing follow, resulted in changes in coloration properties in addition antimicrobial activities of the functionalized/pigment printed wool, wool/polyester blends, i) adding 20g/kg of triclosan derivative to printing formulations results in a considerable increase in the K/S of the pigment prints obtained, as measured by K/S values, as well as enhancement in several of the examined properties of fastness, irrespective of the pigment colourant and substrate used, ii) the improvement of coloration properties reflect the potential effect of triclosan on facilitating and improving the degree of formation of binder-film and crosslinking on the surface of fabrics, as a result, the entrapment is also supported and aided, during the fixation step, more pigment particles are lodged and fixed within/onto the modified binder film/fabric matrix (2, 15, 16), i.e. K/S and good fastness properties, iii) the percentage increases in K/S values are listed in decreasing order: wool/polyester> wool and pigment Blue 153 > pigment Red 146, while all other variables remain constant, iv) triclosan derivative immobility onto/within the fabric and/or within the crosslinked fabric/network matrix using the reaction resin or via electrostatic bonds with active wool element sites, and/or through the interactions between the pigment/crosslinker/binder/substrate, is followed by a marked enhancement in the antimicrobial activities of the resulted prints against by the selected G-ve and G+ve bacteria is follows in descending order: G+ve> G-ve, most likely because to differences in their walls of cells, v) the antimicrobial effect given to a functionalized wool and wool/polyester prints is ruled by the type of material: wool/polyester > wool, and the type of pigment colourant: pigment Red 146 > pigment Blue 153, with all other parameters held constant, and vi) the antimicrobial functionality of triclosan-loaded wool and wool/polyester prints is most likely determined by its ability to inhibit fatty acid biosynthesis by blocking lipid biosynthesis As a

result, both cell membrane construction and reproduction are hampered (17-19).

Table 2. Effect of inclusion of Ruco® - BAC MED into the pigment printing formulations on the printing properties and antimicrobial properties of pigment prints different colors

Pigment Colors	Substrate		K\S	Incr. in K/S (%)	WF		RF		PF				LF	Antimicrobial Activity (zone mm)	
					Alt	C	Dry	Wet	Acidic		Alkaline			G +ve	G −ve
									Alt	C	Alt	C			
Pigment Red 46	W	UT	11.18	78.17	3	3-4	4	4	4	3-4	3	3	2-3	0.0	0.0
		T	19.92		4-5	4-5	4-5	4	4	4	4	4-5	3-4	19.0	18.0
	W/PET	UT	15.34	31.55	3	3	3	2-3	4	4	2-3	4	4	0.0	0.0
		T	20.18		4-5	4-5	4-5	4-5	4-5	4-5	4-5	5	4	20.5	19.0
Pigment Blue 15:3	W	UT	10.92	22.25	3	2-3	4-5	4	4-5	2-3	4	3	2-3	0.0	0.0
		T	13.35		3-4	4	4-5	4-5	4-5	4	4-5	4-5	4-5	17.0	16.0
	W/PET	UT	13.03	22.10	2-3	4-5	4	3	3	4	4	4-5	2-3	0.0	0.0
		T	15.91		4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5	18.0	16.0

- Pigment printing conditions: Pigment color (20 g/kg); DAICO-Thick.1600 (20 g/kg); Printofix® Binder MTB-01 (100 g/kg); Knittex® FEL crosslinking agent (10 g/kg); ammonium persulfate (2 g/kg); Ruco® - BAC MED (20 g/kg).
- Microwave fixation at 1300W/4min. followed by after –washing at 40˚C for 15 min in presence of (2 g/L) nonionic wetting agent.
- K/S: color depth; WF: wash fastness; Alt: alteration; C: staining on cotton; RF: rubbing fastness; PF: perspiration fastness; LF: light fastness; ZI: zone of inhibition; W: wool; W/ PET: wool/ polyester blend; UT: untreated; T: Pigment printed with Ruco® - BAC MED.

4. Conclusion

Individual inclusion of PEG-600 (20g/kg) and Ruco® - BAC MED (20g/kg) in the pigment printing paste [pigment color (20g/kg); binder (100g/kg); synthetic thickening agent (20g/kg); ammonium persulfate $(NH_4)_2S_2O_8$ (2g/kg); crosslinking agent (10g/kg)] followed by screen printing and microwave fixation successfully improved the antibacterial functionality/pigment printability of pigment of wool and Printability, or the depth of the pigment printings created, as well as fastness and antibacterial activity, have all improved significantly. The following is a list of the improvements in antimicrobial activities and K/S values of the pigment printings: PEG-600 > Ruco® - BAC MED >> None regardless of the pigment colourant utilized, the functionalized pigment prints demonstrated exceptional fastness.

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