Antibacterial Functionalization and Pigment Coloration of Wool-containing fabrics in One Step

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Abstract:

In this work, Choline Chloride, Aloe vera and Chitosan, an ecofriendly bioactive agents, were individually included in pigment printing formulation [pigment color (20 g/kg); synthetic thickening agent (20 g/kg); binder (100 g/kg); crosslinking agent (10 g/kg); ammonium persulfate $(NH_4)_2S_2O_8$ (2 g/kg)] followed by printing and microwave fixation at 1300W/4 min to investigate their impacts on simultaneous functionalization and coloration of wool-containing fabrics. The obtained results signify that the antibacterial efficacy as well as the depth of the obtained functionalized pigment prints are affected by nature of bioactive agent as well as kind of substrate and follow the decreasing orders:
Choline Chloride (5g/Kg) > Chitosan (2.5g/Kg) > Aloe vera (10g/Kg) >> none and polyester/wool > wool respectively.

Keywords:

Wool-containing fabrics
Pigment Printing
antibacterial finishing
One-step
Bio-active agents

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1- Introduction

Textiles especially natural ones are excellent environment for the growth of microorganism (bacteria, fungi, algae, dust mites and yeast). The growth of microorganisms on textiles causes a lot of negative impacts on the wearer such as infection by pathogenic micro organisms, unpleasant odor and also on the textile itself such as stains, discoloration and loss in mechanical strength, therefore, it is very important to stop and/or minimize the growth of microbes on textiles during their use and storage by using antimicrobial agents (1,2). The antimicrobial agents inhibit microorganisms in different ways. Generally, attacks the cell wall of the microbe, inhibits the cell wall synthetics, and alters the cytoplasmic membrane permeability. It also alters the physical or chemical state of proteins and nucleic acid synthesis, and inhibits the enzyme action (1,3-5).

Recently many efforts have been carried out to impart functionality to textile by using different antibacterial agents to destroy and/or control bacterial growth such as: nanomaterials, quaternary ammonium salts, bioactive agent, neem oil, clove oil, triclosan and chitosan (5-9).

The main task of this research is to impart antibacterial functionality and enhance pigment printability of wool and wool/polyester blends fabrics in one step through inclusion of eco-friendly bio-active agents namely choline chloride, Aloe vera or chitosan as antibacterial agents into the pigment paste formulations followed by printing and microwave fixation.

2- Experimental

2.1. Materials

The fabric used in this study was mill-scoured, semi-bleached wool fabric (220g/m2) and polyester/wool (50/50, 230g/m^2) blend.

DAICO® Thick. 160 (synthetic thickener based on polyacrylate, Daico, Egypt), Printofix® Binder MTB-01 liquid (binding agent based on acrylate copolymer, Clariant), Knittex® FEL crosslinking agent (reactant crosslinking agent based on a modified dimethylol dihydroxy ethyleneurea, Huntsman), Chitosan (degree of deacetylation > 82.9%, Sigma), Pigment Red 146 and Pigment Blue 153 (Daico, Egypt) were of commercial grade.

Aloe gel was extracted from Aloe vera plant, available in Egypt using methanol as a solvent (10). All other chemicals used in this study such as ammonium persulphate $[(NH_4)_2S_2O_8]$, choline chloride and acetic acid were of laboratory regent grade.

2. 2. Methods

2.2.1. Antibacterial finishing and printing in a simultaneous process

The wool and polyester/wool fabric samples were antibacterial finishing and pigment printing 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:	
Choline Chloride	0-20g
Alo vera	0-20g
or Chitosan	0-10g
H_2O	X g

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 (11):

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

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 and Discussion

The present work focuses on upgrading the antibacterial functionality and pigment printing capacity of wool and polyester/wool fabric samples through individual inclusion of antibacterial bio-active agents namely choline chloride, Alo vera and chitosan in printing paste, followed by screen printing and microwave fixation.

3.1. Pigment coloration

Fig. 1 (a) reveals that i) increasing the amount of choline chloride up to 5g/Kg in the printing paste brings about an improvement in K/S printed samples, ii) the increase in K/S values of printed samples reflects the positive role of the used choline chloride on modifying the surface of fabrics, via addition of new reactive sites, thereby affording more centers for fixation of pigment particles onto/within the binding agent/fabric matrix during the fixation step (12), and iii) the increase in the K/S of printed samples is affected by kind of fabric, e.g. structure of fabric, extent of surface modification, available active sites, and degree of fixation of choline chloride and/or pigment particles during the fixation step (13, 14), vii) the K/S of obtained functionalised pigment prints follows the decreasing order: polyester/wool > wool which could be discussed in terms of the undue-penetration of printing paste components in the wool structure (14).

Fig. 1 (b) shows that i) inclusion of Aloe vera gel, 10gKg, in the printing formulation leads to an increase in the depth of color of the obtained printings, ii) the improve in the K/S value is affected by kind of fabric: polyester/wool (K/S= 19.89) > wool (K/S= 15.15), iii) this improvement in the K/S value is attributed to the positive influence of the active chemical components of Aloe vera gel and their active groups, e.g. – OH, -COOH, -NH_2 groups **(15,16)** and, iv) increase concentration of Aloe vera gel beynod 20 g/Kg leads to a decrease in K/S value due to minimization of degree of fixation of pigment particles onto fabric surface, regardless of the used substrate.

Fig.1 (c) demonstrates that i) increasing the concntration of chitosan up to 2.5 g/Kg in the pigment paste leads to upgrading of depth of shade of wool and polyester/wool printed samples, ii) this enhancement in depth of shade is due to increase the encapsulation and fixation of the pigment particles at fabric surface through improving the film forming propertie, which in turn more reactive centers providing like –NH_2 and –OH groups, for both crosslinking and pigment particles accommodation (17-20), iii) by increasing the concentration of chitosan beyond 2.5 g/Kg, the depth of shade of printed samples is reduced and this may be due to the increase in viscosity of the printing paste and thereby reducing paste uptake, binder film formation and subsequent pigment particles entrapment during the fixation step. Moreover, K/S of the obtained prints followed the decreasing order: polyester/wool > wool, due to the differences in fabric structure, porosity, thickenes, available active sites on fabric surface, thereby affecting fixation and adhesion of the binder film-to-fibre and the extent of penetration of pigment particles (14, 21).

Table 1. demonstrates that effect of individual incorporation of choline chloride (5g/Kg), Aloe vera (10g/Kg) and chitosan (2.5g/Kg) into pigment paste on antibacterial functionality/printing properties of printed wool and wool/polyester blends using different pigment colorants. It is clear that: i) inclusion of the nominated antibacterial agents into the pigment paste leads to an outstanding enhancement in the antibacterial efficacy, expressed as zone of growth inhibition (ZI, mm), against both the Gram-positive (S. aureus) and Gram-negative (E. coli) bacteria, ii) this enhancement in antibacterial activity determined by type of substrate: polyester/wool > wool, kind of antibacterial agent: choline chloride > chitosan > Alo vera >> none, ii) the differences between antibacterial activity of the produced pigment printings may be ascribed to differences in active components, i.e. cationic quaternary

ammonium salt in choline chloride, antiseptic agent like lupeol, salicyclic acid, cinnamonic acid, phenols and sulfur in Aloe vera or amino groups in chitosan, as well as degree of fixation onto the printed fabric surface with other components of printing paste during fixation step(16,19, 22, 23), iii)) the antibacterial activity against the nominated bacteria follows the descending order G+ve > G-ve, indicating differences between them in membrane structure, response for inactivation and ability to resist damage and destruction(12), iv) inclusion of choline chloride, Alo vera and chitosan into the printing paste leads to aremarkable enhancement in prinability , i.e. depth of shade (K/S) and fastness properties of printed samples, v) this improvement in printing properties reflects the positive role of used choline chloride, Alo vera and chitosan in moditying the fabric surface and creating a new active sites for fixation of pigment particles on/within the binding agent/fabric matrix during fixation step and vi) the differences among the nominated bio-active agents are ascribed to their variation in chemical structure, active groups, degree of fixation and interaction with other components during the microwave fixation step(18,20,24).

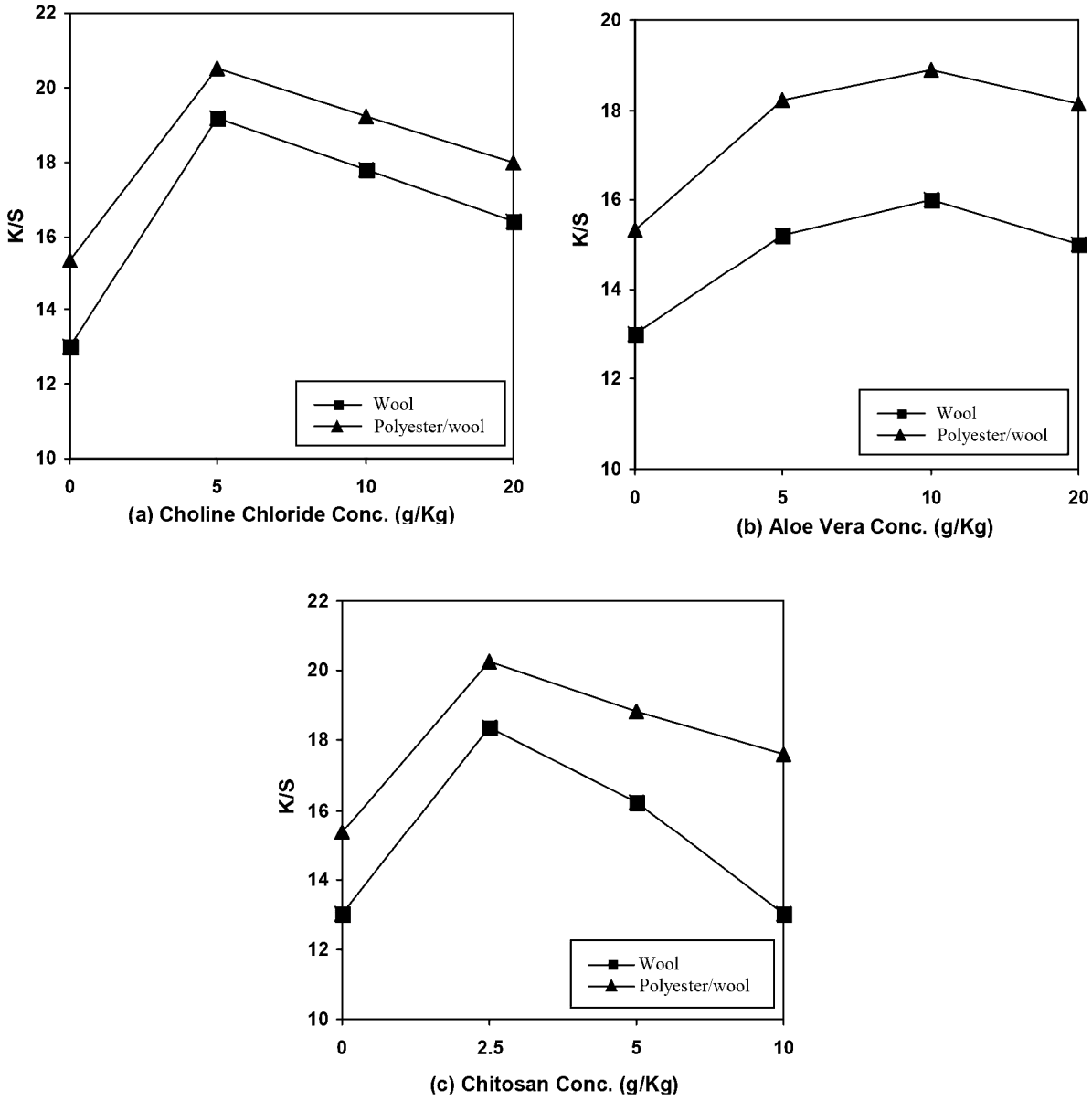

Fig.1. Effect of incorporation of Choline Chloride (a), Aloe vera (b) and Chitosan (c) into pigment paste on K/S values of the obtained prints.

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$(NH_4)_2S_2O_8$ (2 g/kg); the absence and presence of Choline Chloride (0-20g/Kg), Aloe vera (0-20g/Kg) or Chitosan (0-10g/Kg). Microwave fixation: 1300W/4min.

3.2. Antibacterial functionality

Table1. Effect of incorporation of Choline Chloride, Aloe vera and Chitosan into pigment paste on Antibacterial/printing properties of printed wool and wool/polyester blended fabrics using different pigment colorants

Pigment	Substrate	Additive	K\S	WF		RF		PF				LF	ZI (mm)	
				Alt	St.	Dry	Wet	Acidic		Alkaline			G +ve	G −ve
								Alt	C	Alt	C			
Pigment Red 146	Wool	None	13.01	3	3-4	4	4	4	3-4	3	3	2-3	00.0	00.0
		Choline Chloride	20.01	4	4	4-5	4-5	4	4	3-4	4	4	20.0	18.0
		Aloe vera	15.15	3-4	4	4-5	5	4-5	5	3-4	3-4	3-4	7.0	9.0
		Chitosan	18.36	4	4	4	4-5	4-5	5	4	4	4	20.0	17.0
	Wool/polyester	None	15.34	3	3	3	2-3	4	4	2-3	4	4	00.0	00.0
		Choline Chloride	20.53	3-4	4	3-4	4	5	4-5	4	5	4-5	23.0	22.0
		Aloe vera	19.89	4-5	3-4	4	3-4	4-5	4-5	4	4-5	5	10.0	10.0
		Chitosan	20.28	4-5	4	4	4	4	4-5	4	5	5	20.0	18.0
Pigment Blue 153	Wool	None	10.92	3	2-3	4-5	4	4-5	2-3	2-3	3	4	00.0	00.0
		Choline Chloride	15.59	3-4	4	5	4-5	5	4	4	3-4	4-5	25.0	20.0
		Aloe vera	12.84	4	4	5	4-5	5	4-5	4-5	4	4-5	6.0	6.5
		Chitosan	14.12	3-4	4	5	4-5	5	3-4	4-5	4-5	4-5	17.0	17.0
	Wool/polyester	None	13.03	2-3	4	4	2-3	2-3	4	2-3	3-4	2-3	00.0	00.0
		Choline Chloride	16.11	4	5	4-5	4	4	4-5	4	5	4	25.0	21.0
		Aloe vera	15.19	4	5	4	4-5	3-4	5	5	5	4	19.5	6.5
		Chitosan	15.24	3	5	4	4-5	4	4	4-5	4-5	4	22.0	21.0

- 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); the absence and presence of Choline Chloride (5g/Kg), Aloe vera (10g/Kg) or Chitosan (2.5g/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.

4- Conclusion

We have successfully upgraded the antibacterial functionality/pigment printabilty of pigment of wool and polyester/wool blended fabrics via individual inclusion of choline chloride (5g/Kg), Aloe vera (10g/Kg) and chitosan (2.5g/Kg) in the pigment formulation [pigment color (20g/kg); synthetic thickening agent (20g/kg); binder (100g/kg); crosslinking agent (10g/kg); ammonium persulfate $(NH_4)_2S_2O_8$ (2g/kg)] followed by screen printing and microwave fixation. printability, i.e. the depth of the produced pigment printings, fastness properties in addition to an outstanding improvement in their antibacterial activity. The improvement in antibacterial activity and K/S values of the obtained pigment printings, follows the descending order: choline chloride > chitosan > Alo vera >> none. The functionalized pigment prints showed a remarkable fastness properties, irrespective of the used pigment colorant.

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