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Functional finishes of stretch cotton fabrics

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ABSTRACT

Functionalized cotton cellulose/spandex woven fabrics with different structures namely plain (1/1), twill (2/2) and satin were produced. Factors affecting the imparted functional properties such as weave structure and constituents of the finishing formulations including ether or ester cross-linker and catalyst type, silicone-micro-emulsion, water/oil repellent, Ag-NP·s and TiO_2-NP·s were studied. The treated fabrics were found to have easy care property together with one or more of the imparted functional properties such as soft-handle, water/oil repellence, antibacterial, UV-protection and self cleaning. The effectiveness of the imparted properties is not seriously affected even after 10 washing cycles. Surface modifications as well as the composition of certain samples were confirmed by SEM images and EDX spectra. Mode of interactions was also suggested.

1. Introduction

Spandex is a linear, segmented poly (urethane–urea) elastomer generally used in the fiber form and known for its exceptional elasticity. Its performance characteristics is governed by segment size, hard segment content, chemistry of hard and soft segment as well as degree of microsphere separation. For clothing, spandex is usually used as the core and covered with natural fibers or synthetics, and accounts for small percentage of the final product (3–12%) for retaining most of the look and feel of the sheath or the shield fibers. Therefore elastic core-spun yarns can be used to produce of knitted and woven fabrics of varying styles, handle, and functions taking in consideration the comfort concern (Dhouib, El-Ghezal, & Cheikhrouhou, 2006; El-Ghezal, Babay, Dhouib, & Cheikhrouhou, 2009; Mashaly & Hussein, 2011; Su, Maa, & Yang, 2004).

To date, there is still great demand for more and more innovative cellulose-containing textile products with high performance and functional properties such as easy care, softness, solar protection, antimicrobial, self-cleaning, together with better added value are urgently needed for numerous potential applications to comply with the ever growing consumers awareness and demands (Bajaj, 2002; Hashem, Ibrahim, El-Shafei, Refaie, & Hauser, 2009; Holme, 2007; Ibrahim, Abo-Shosha, El-Nagdy, & Gaffer, 2002; Ibrahim, Gouda, El-Shafei, & Abd el-Fattah, 2007; Ibrahim, Aly, & Gouda, 2008; Ibrahim, Eid, Hashem, Refaie, & El-Hossamy, 2010, Ibrahim, Refaie, & Ahmed, 2010, Ibrahim, Abdel Rehim, & El-Batal, 2010, Ibrahim, Khalifa, El-Hossamy, & Tawfik, 2010, Ibrahim, Amr, Eid, El-Sayed, & Fahmy, 2012; Ibrahim, Eid, Youssef, El-Sayed, & Sabah, 2012, Ibrahim, Eid, & El-Batal, 2012, Ibrahim, Eid, Abou Elmaaty, & Abd Elaziz, 2013; Liu & Dong, 2002; Shao, Sun, & MengW. Qing, 2004; Wilson, Bevin, Lourig, & Niven, 2008). To cope with the aforementioned requirements, proper fabric structure and components, active ingredients, compatibility with other ingredients in the finishing formulations as well as finishing technique should be taken in consideration together with the environmental and economical concerns.

Therefore, the main task of the present work is to enhance the functional properties of cotton fabrics whose weft yarns are cotton covered spandex-core spun yarns.

2. Experimental

2.1. Materials

Mill scoured and bleached cotton/spandex woven fabrics namely: plain (1/1) weave blend (152 g/m^2; thickness 0.310 mm;

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spandex ratio in the weft cotton wrapped spandex-core spun yarns 7.3%; drawing ratio (2.8%), satin weave blended fabric (189 g/m^2, thickness 0.430 mm; spandex ratio in the weft cotton wrapped spandex core spun yarns 7.3%; drawing ratio 2.8%), as well as twill (2/2) weave blended fabric (180 g/m^2, thickness 0.420 mm; spandex content 7.3%; drawing ratio 2.8%) were used throughout this study.

Toluene 2,4-diisocyanate (TDI, Shanghai Chemicals, China), stearyl alcohols (SAl, Merck) and F6 (a mixture of perfluorinated aliphatic alcohols, (having a hydroxyl content of 2.58 mol per100 g, 3 M Co, USA) were dried under vacuum at 80 °C for 12 h before use. Stearic acid (SAc), triethanolamine (TE.OH.A), citric acid, trisodium citrate, magnesium chloride hexahydrate ($Mg\ Cl_2{\cdot}6H_2O$) sodium hypophosphite monohydrate ($NaH_2PO_2{\cdot}H_2O$), 2-propanol, silver nitrate ($AgNO_3$–Sigma), titanium tetraisopropoxide (Sigma) and nitric acid were analytical reagents grade.

Fixapret ECO® (modified dimethylol dihydroxy ethylene urea, low formaldehyde reactant resin, DMDHEU, BASF), Durex® Silicone 1020 (based on modified polysiloxane micro-emulsion, Texchem, CO, Egypt), and Hostapal® CV-ET (nonionic wetting agent based on alkyl aryl polyglycol ether, Clariant) were of commercial grade. Methylene Blue (C.I. Basic Blue 9, Merck) was used as received.

2.2. Methods

2.2.1. Preparation of TiO_2-nanoparticles (TiO_2-NP·s)

TiO_2-NP′s were prepared as previously reported method (Bozzi, Yuranova, & Kiwi et al., 2005; Bozzi, Yuranova, Guasaquillo, Laub, & Kiwi, 2005) using titanium tetraisopropoxide as a precursor together with 2-propanol and nitric acid.

2.2.2. Preparation of Ag-nanoparticles (Ag-NP·s)

Ag-NP·s were synthesized using trisodium citrate as a reducing agent and $AgNO_3$as a precursor as reported elsewhere (Sileikaite, Prosycevas, Puiso, Juraitis, & Guobiene, 2006).

2.2.3. Preparation, purification and emulsification of SA l/TDI/F6 adduct

The nominated adduct was prepared using a molar ratio of 1/1/1, purified and emulsified as previously described method (Abo-Shosha, El-Hilw, & Amr, 2009).

2.2.4. Easy care/soft finish in one step

The blended fabric samples were padded twice in a finishing formulation containing Fixapret ECO® (50 g/L), silicone micro-emulsion (20 g/L), $MgCl_2{\cdot}6H_2O$ (10 g/L) and nonionic wetting agents (2 g/L) to 80% wet pick up followed by drying/curing in one step in a commercial microwave oven at output power of 386 W/3 min. Finished samples were thoroughly washed with warm and cold water to remove un-reacted and unfixed materials, dried and conditioned before testing.

2.2.5. Easy care/water and oil repellent finish

Fabric samples were padded twice in a finishing formulation containing the prepared SA l/TDI/F6 adduct (50 g/L), Fixapret ECO® (50 g/L), and $MgCl_2{\cdot}6H_2O$ (10 g/L) to 80% wet pick up followed by microwave fixation at 386 W/5 min, thoroughly washed, dried and conditioned before evaluation.

2.2.6. Easy care/antibacterial finish

Fabric samples were padded twice in a finishing formulation including the prepared Ag-NP·s stock finishing solution (50 g/L) citric acid (50 g/L), $NaH_2PO_2.H_2O$ (40 g/L) and nonionic wetting agent (2 g/L), to 80% wet pick-up followed by microwave fixation at 386 W/3 min thoroughly washed, dried and conditioned.

2.2.7. Easy care/antibacterial/UV-protection/self cleaning finish

To confer multifunctional properties on the nominated blended fabrics, the fabric samples were padded twice in a finishing bath containing the prepared TiO_2–NP′s stock finishing solution (20 g/L) citric acid (50 g/L), $NaH_2PO_2{\cdot}H_2O$ (40 g/L) and nonionic wetting agent (2 g/L), to 80% wet pick-up, microwave fixation at 386 W/3 min. followed by thoroughly washing, drying and conditioning before testing.

2.2.8. Self-cleaning

The untreated and TiO_2 – loaded fabric samples were dipped in a Basic Blue dye solution (1% owf) for 15 min for staining, then dried and conditioned. These samples were exposed to day light irradiation for 8 h. The color strength, expressed as K/S value, of untreated and TiO_2 – loaded fabric samples were measured. The K/S values are directly proportional to the amounts of dye present on the substrate .The decrease in K/S values is a direct consequence of the degradation of the dye stains (Bozzi, Yuranova, et al., 2005; Bozzi, Yuranova, Guasaquillo, et al., 2005; Ibrahim, Amr et al., 2012) according to the following equation:

$$\text{Extent of discoloration}\,(\%) = \frac{(K/S)_a \times 100}{(K/S)_b}$$

where $(K/S)_a$: color strength after exposing to daylight and $(K/S)_b$: color strength before exposing to daylight.

2.3. Measurements

Nitrogen content (%N) was determined according to Kjeldahl method. Carboxyl content of the treated fabric samples was determined as described elsewhere (Cirino & Rowland, 1976). Dry wrinkle recovery angle (WRA) was determined according to ASTM method S-1296-98. Roughness of the treated and untreated fabric samples was assessed using roughness measuring instrument SE 1700α, Japan, according to JIS 94 standard. Water repellency testing (WRR) was performed using the spray test method 22-1989. Oil repellency rating (ORR) was measured according to AATCC test method 118-2007. Antibacterial activity assessment against

Table 1
Effect of weave structure on the extent of easy care/soft finish[a].

Weave structure	%N[b]	WRA[c] (W + F)°	Roughness (μm)	Retained property (10 washing cycles)	
				WRA (W + F)°	Roughness (μm)
Plain (1/1)	0.640	252 (188)	8.53 (14.42)	240	9.02
Twill (2/2)	0.670	270 (205)	7.32 (14.13)	255	7.06
Satin (4)	0.689	285 (215)	6.22 (13.25)	272	6.83

Values between parentheses correspond to the untreated fabrics.
[a] Finishing formulation: Fixapret® ECO (50 g/L); silicone softener (20 g/L); $MgCl_2{\cdot}6H_2O$ (8 g/L); nonionic wetting agent (2 g/L); wet pick-up (80%); microwave fixation at 386 W/3 min.
[b] %N: nitrogen content.
[c] WRA (W + F)°: wrinkle recovery angle (weft + warp).

G+ve (*S. aureus*) and G−ve (*E. coli*) bacterial was evaluated qualitatively according to AATCC Test Method (147-1988), and expressed as zone of growth inhibition (ZI, mm). UV-Protection factor (UPF) was determined according to the Australian/New Zealand Standard AS/NZS 4399-1996). The color strength (*K*/*S*) values were determined from the reflectance measurements using Kubleka–Munk equation (Judd & Wyszecks, 1975).

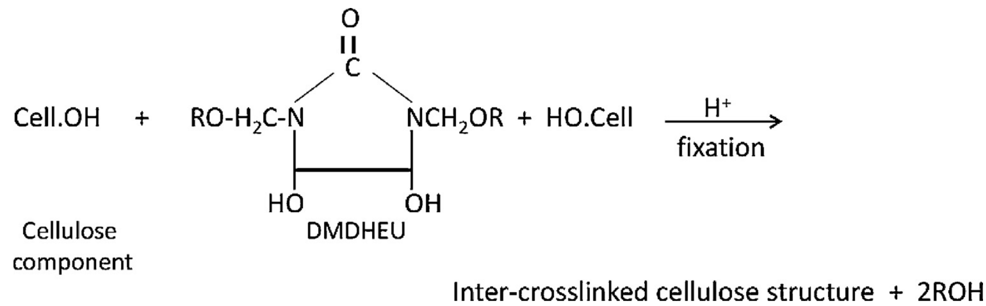
$K/S = (1 - R)^2/2R$, where K/S is the ratio of absorption and scattering coefficient, R is the reflectance at the wave length of maximum absorbance of the used basic dye. The durability to wash was determined after 10 laundering cycles according to AATCC Test Method 135-2000. The surface morphology of selected samples was observed with SEM Model Quanta SEM 250 FEG (Field Emission Gun) attached with EDX unit (Energy Disperse X-ray Analysis with accelerating voltage – 30 kV FEI Co., Netherlands) for the composition analysis of nano-Ag and TiO_2-loaded fabric samples.

3. Results and discussion

In the present work, we aim at understanding the effect of type of finishing formulation as well as construction of cotton/spandex (82.7/17.3) woven fabric on kind and extent of functionalization under various conditions. Results obtained along with their appropriate discussion follow.

3.1. Easy care/soft finish

As far as the changes in the nitrogen content (%N), as well as the easy care (WRA) and softness, expressed as roughness value, functional properties as a function of weave structure, the data in Table 1 signify that: (i) easy care/soft-finish of the plain, twill and satin cotton/spandex (82.7/17.3) woven fabrics is accompanied by an enhancement in the %N, WRA as well as a decrease in the fabric roughness, i.e. an increase in softness degree, regardless of the used weave structure, (ii) the enhancement in the a aforementioned properties is a direct consequence of enhancing the extent of ether-crosslinking within the accessible regions with hydroxyl groups of cotton cellulose in the presence of the used acid-liberating catalyst, i.e. $MgCl_2{\cdot}6H_2O$ during the microwave fixation step as follows (Bajaj, 2002; Ibrahim, Amr et al., 2012):



(1)

thereby improving both the %N and fabric resiliency, WRA, of the finished substrates, (iii) inclusion of the silicone micro-emulsion in the same finishing formulation results in improving the imparted easy care property and softness functionality via reduction of bending strength due to. Its lubricating effect that decreases fiber/fiber friction and improved drape ability and/or via combination of crosslinking plus lubrication (Hashem et al., 2009; Ibrahim, Khalifa, et al., 2010; Schindler & Hauser, 2004a, chap. 3), (iv) the extent of improvement in the %N as well as in the imparted easy care and softness functional properties is governed by type of the treated substrate, i.e. fabric construction, weight, thickness, availability and accessibility of cellulose-component active sites, —OH groups, extent of loading, location and distribution of both the finishing and softening agent onto/within the fabric structure, (v) both the %N and the modified fabric resiliency is attributed to the spandex as a core component in the treated woven fabrics (Su et al., 2004), and (vi) increasing the washing cycles up to 15 has practically a reasonable negative impacts on the imparted functional properties.

3.2. Easy care/water and oil repellent finish

Presence of SA l/F6/TDI emulsified adduct, as a water and oil repellent, along with DMDHEU, as a cross-linker, and $MgCl_2{\cdot}6H_2O$, as a catalyst, followed by micro-wave fixation would be expect to promote fixation of the nominated adduct onto the treated blended fabric surfaces as follow:

$$\underset{\text{(SAL)}}{\text{St.OH}} + \underset{\text{TDI}}{\text{OCN-TDI-NCO}} + \underset{\text{F6}}{\text{F6}{\sim}\text{OH}} \xrightarrow{\Delta} \underset{\text{Adduct}}{\text{St.OOCHN–TDI-NHCOO-F6}} \quad (2)$$

$$\text{St.OOCHN} - \text{TDI} - \text{NHCOO} - F6 + \text{DMDHEU} + \text{HO.Cell} \xrightarrow[\Delta]{H^+} \text{Crosslinked/adduct} - \text{loaded substrate} \quad (3)$$

$$\text{Adduct} + \text{DMDHEU} \xrightarrow[\Delta]{H^+} \text{Corsslinked adduct deposits} \quad (4)$$

As far as the changes in the imparted %N, WRA, WRR and ORR chemical and functional properties of the finished substrates upon utilizing the emulsified adduct as water/oil repellent, the data in Table 2 demonstrate that, (i) the extent of variation in the aforementioned properties is determined by the type of weave structure and follows the descending order: stain > twill > plain, regardless of the imparted property, (ii) this reflects the positive impact of loading and/or binding the nominated adduct covalently to the hydroxyl groups of the cellulose component (Eq. (3)) and/or via deposition as a cross-linked deposits onto the fabric surface (Eq. (4)), and as

Table 2
Effect of weave structure on the extent of easy care/water and oil repellent finish[a].

Weave structure	%N[b]	WRA[c] (W + F)°	WRR[d]	ORR[e]
Plain (1/1)	0.690 (0.664)	268 (255)	70 (50)	6 (3)
Twill (2/2)	0.710 (0.680)	280 (270)	80 (50)	7 (4)
Satin (4)	0.721 (0.694)	295 (283)	80 (50)	8 (5)

Values between parentheses correspond to the retained properties after 10 washing cycles; WRR and ORR values of untreated substrates = zero.
[a] Finishing formulation: Fixapret® ECO (50 g/L); water/oil repellent (50 g/L); $MgCl_2{\cdot}6H_2O$ (8 g/L), wet pick-up (80%); microwave fixation at 386 W/3 min., followed by one cycle-after wash.
[b] %N: nitrogen content.
[c] WRA (W + F)°: wrinkle recovery angle (warp + weft).
[d] WRR: water repellent rate.
[e] ORR: oil repellent rate.

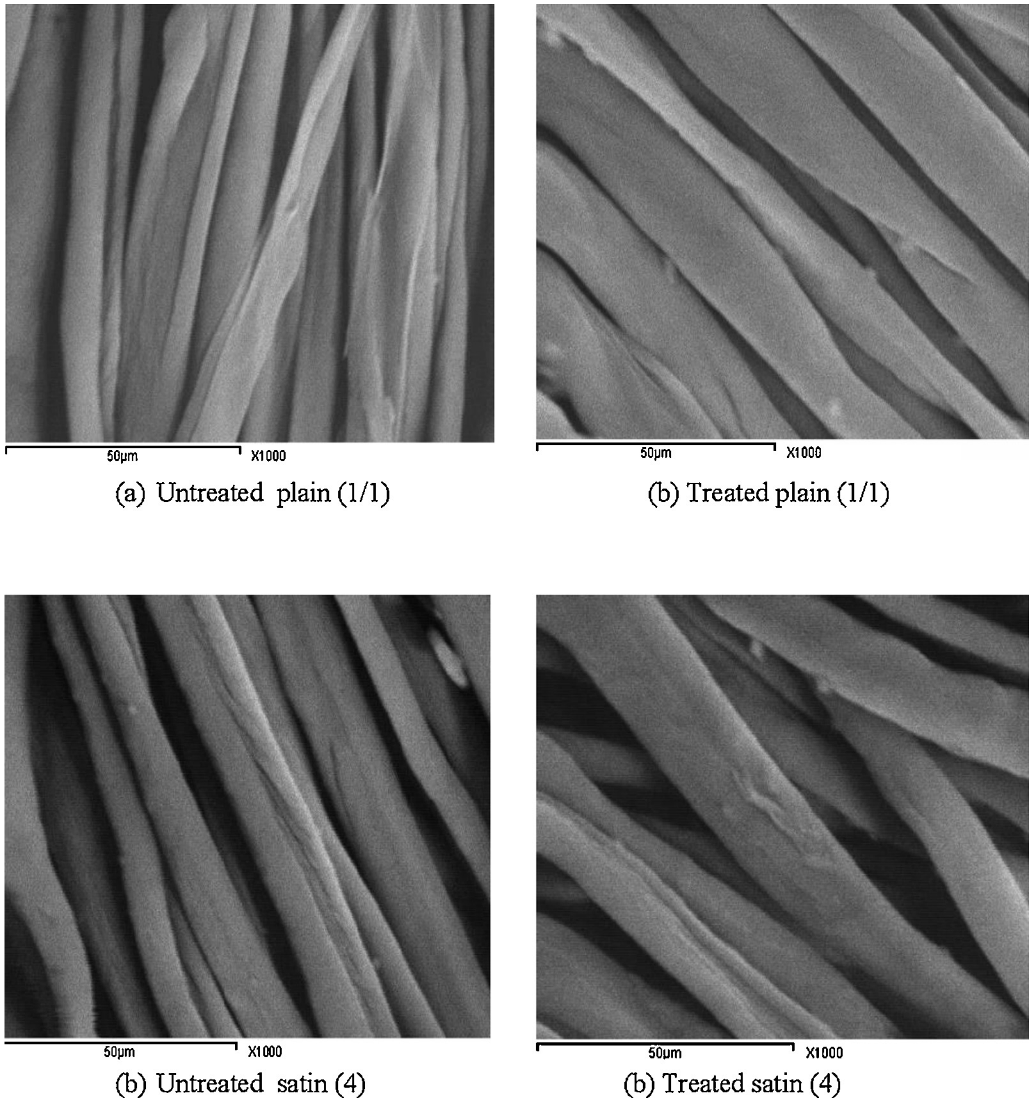


Fig. 1. SEM images of untreated plain (a), treated plain (b), untreated satin (c) and treated satin and (d) fabric samples.

confirmed by SEM images of some selected samples (Fig. 1), (iii) the enhancement in the %N, fabric resiliency as well as the water and oil repellent functionality is a direct consequence of loading the nominated adduct and its lubricating and smoothening effects, together with a direct consequence of presence of a long hydrocarbon tail of SAl in the adduct thereby ensuring better distribution of the fluorochemical segments together with their orientation, i.e. enhanced water/oil repellent (Abo-Shosha & Ibrahim, 1992; Abo-Shosha, El-Sayed, Fahmy, & Ibrahim, 2005; Abo-Shosha et al., 2009; El-Sawy, Abo-Shosha, Abdel-Mahdy, & Ibrahim, 1995; Schindler & Hauser, 2004b, chap. 6), (iv) the change in weave structure is accompanied by a variation in the extent of cross-linking, loading of the emulsified adduct physically, mechanically and/or chemically, as well as hydrophilic/oleophobic property, and (v) increasing the washing cycles up to 10 is accompanied by a decrease in the imparted properties, regardless of the used weave structure, most probably as a direct consequence of the removal of mechanically entrapped adduct within the cross-linked/fabric network as well as the unfixed surface adduct deposits onto the finished fabrics surface.

3.3. *Easy care/antibacterial finish*

For a given set of dual finish conditions, results of Table 3 show that: (i) ester-crosslinking of the nominated substrates brings

Table 3
Effect of weave structure on the extent of easy care/antibacterial finish[a].

Weave structure	Carboxyl content (meq./100 g)	WRA[b] (W + F)°	ZI[c] (mm)	
			G+ve	G−ve
Plain (1/1)	38.21	235 (223)	15 (11)	12 (9)
Twill (2/2)	45.66	258 (243)	17 (11)	15 (10)
Satin (4)	53.63	270 (255)	20 (16)	18 (12)

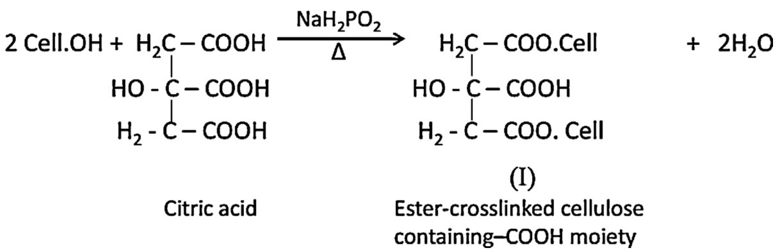
Values between parentheses correspond to the retained antibacterial activity after 10 washing cycles. ZI values of untreated substrates= zero.

[a] Finishing formulation: citric acid (50 g/L); $NaH_2PO_2 .H_2O$ (40 g/L); Ag-NPs solution (20 g/L); wet pick up (80%); microwave fixation at 386 W/3 min., followed by one cycle after wash.

[b] WRA (W + F)°: Wrinkle recovery angle (warp + weft).

[c] ZI: Zone of inhibition.

about a remarkable creation of new active groups, i.e. COOH groups, as a direct consequence of ester-crosslinking of cellulose chains through the formation of cyclic anhydride in the presence of NaH_2PO_2 as a catalyst, (Ibrahim et al., 2002; Ibrahim, Amr et al., 2012) as follows:



(5)

$$n\,\text{Citric acid} \underset{\Delta}{\overset{NaH_2PO_2}{\longrightarrow}} \underset{\text{(II)}}{\text{crosslinked polycarboxylic acid deposits}} \quad (6)$$

(ii) the carboxyl content is determined by the type of substrate and follows the decreasing order: stain (4) > twill (2/2) > plain (1/1) most probably attributed to the fixation of the finish components onto/within the fabric structure and the subsequent formation of ester cross-links (Eq. (5)) and/or cross-linked polycarboxylic acid deposits onto/in the fabric structure, (iii) the improvement in the fabrics resiliency follows the above mentioned order of carboxyl content, (iv) incorporation of the synthesized Ag-NP·s, using Na-citrate as a reductant, with an average particle size < 9 nm (Fig. 2a) into the ester-crosslinking formulation results in imparting antibacterial functionality against the G+ve (*S. aureus*) and G−ve (*E. coli*) bacteria, regardless of the treated substrate, (v) the imparted antibacterial activity is attributed to enhancing the extent of loading Ag-NP·s onto the fabrics surface as well as their fixation via the built in active sites, i.e. COOH groups and their damaging effect on bacterial membrane and/or their ability to generate reactive oxygen species in the presence of dissolved oxygen which in turn causing oxidation of the molecular structure of bacteria (Mahapatra & Karak, 2008; Jones & Hock, 2010; Ibrahim et al., 2013), (vi) the difference in antibacterial activity against the nominated bacteria is a direct consequence of their differences in the cell wall structure and amenability to disruption (Orhan, Kut, & Gunesoglu, 2009; Jones & Hock, 2010).

On the other, the data in Table 3 signify that increasing washing cycles up to 10 cycles, has practically a slight effect on the imparted functional properties, which might be attributable to the removal of unfixed and/or entrapped Ag-NP′s and citric acid onto/within the finished fabric samples.

Additionally, SEM images of the Ag-NP′s-loaded plain (1/1) and satin (4) fabrics were illustrated in Fig. 3a and e respectively together with their corresponding EDX spectra Fig. 3b and d respectively confirm the presence of silver on the treated substrates.

3.4. Multifunctional finish

The effect of weave structure on the extent of multifunctional finishing is studied. The obtained results Table 4, indicate that: (i) easy care finishing in the presence of TiO_2-nanosolparticle size < 9 nm (Fig. 2b), as a functional additive, results in enhancing the carboxyl content, the fabric resiliency, antibacterial activity, anti-UV functionality, as well as self cleaning property of the treated substrates, (ii) the enhancement in the above mentioned properties is determined by type of substrate and follows the decreasing order: Stain (4) > Twill (2/2) > Plain (1/1), regardless of the imparted property, (iii) the improvement in both —COOH content and WRA values reflects the positive impact of ester-crosslinking, using citric acid, NaH_2PO_2 finishing system on modification of the cellulose structure (Eqs. (5) and (6)) as well as fixation of the TiO_2-NP·s via the introduced new active sites, —COOH groups, onto/into the cellulose structure, (iii) the imparted antibacterial activity against the nominated G+ve and G−ve bacteria, expressed as ZI values, is a direct consequence of the photo-catalytic properties of the loaded TiO_2-NP′s and generation of highly active oxygen-containing species having the capability to oxidize organic compounds of bacterial cells (Dastjerdi, Montazer, & Shahsavar, 2010; Ibrahim, Eid et al., 2012; Ibrahim, Amr et al., 2012), (iv) the antibacterial activities for all treated samples against the nominated bacteria follows the decreasing order: G+ve >G−ve bacteria, (v) the great enhancement in the anti-UV functionality, expressed as UPF values, by loading of TiO_2-NP′s onto the cross-linked cellulose structure is attributed to the screening/absorption ability of the treated samples to the

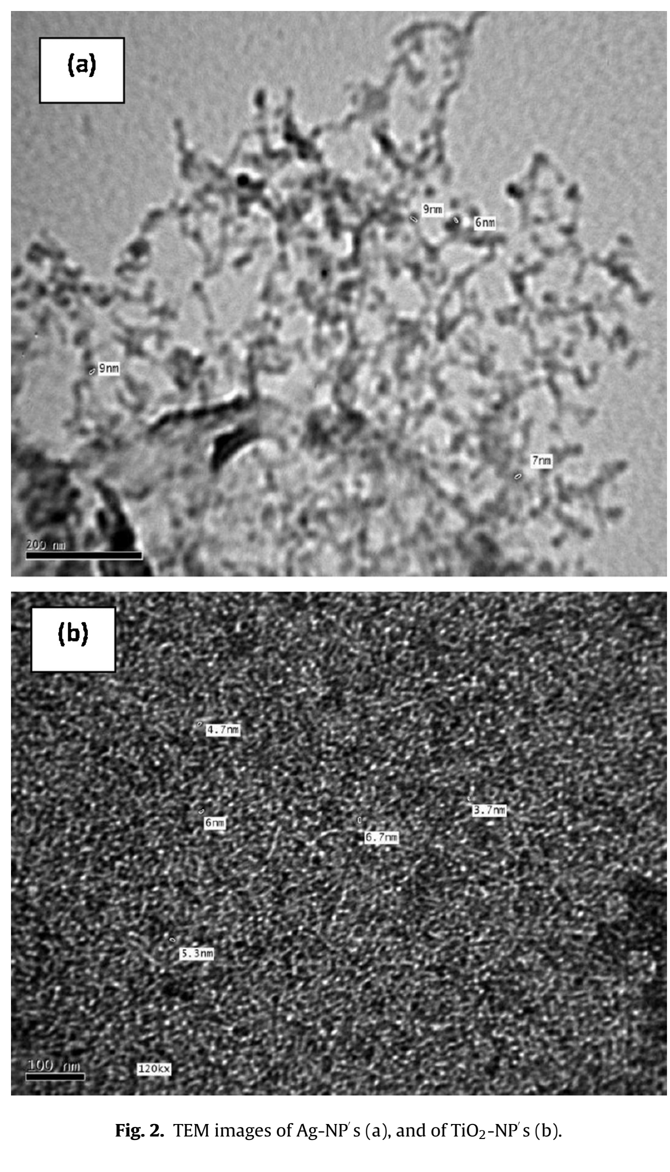


Fig. 2. TEM images of Ag-NP′s (a), and of TiO_2-NP′s (b).

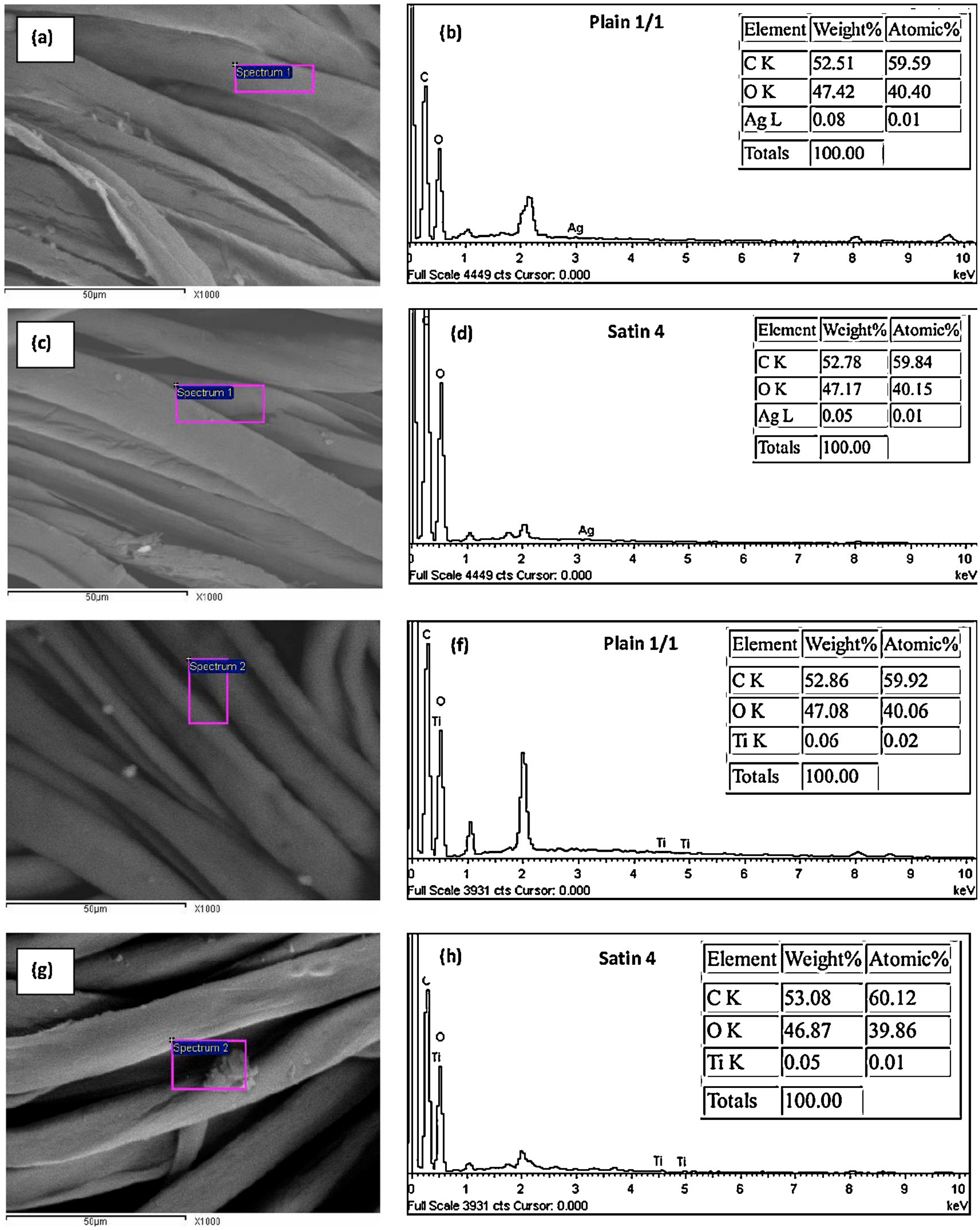


Fig. 3. SEM images and EDX spectra of: Ag-NP's-loaded plain (1/1) and Satin (4) fabrics (a)–(d), TiO_2-NP's-loaded plain (1/1) and Satin (4) fabrics (e)–(h).

Table 4
Effect of weave structure on the extent of multifunctional (easy care/antibacterial/anti-UV/self-cleaning) finish.[a]

Weave structure	Carboxyl content (meq/100 g)	WRA[b] (W + F)°	ZI[c] (mm)		UPF[d]	Extent of discoloration (%) (λ_{max} = 665)
			G+ve	G−ve		
Plain (1/1)	30.93	225 (216)	16 (13)	14 (12)	25 (20)	78.8 (75.2)
Twill (2/2)	40.91	240 (232)	18 (16)	16 (14)	36 (30)	89.3 (85.5)
Satin (4)	48.60	250 (245)	21 (18)	18 (15)	45 (40)	96.5 (90.9)

Values between parentheses correspond to the retained functional properties after 10washing cycles.
[a] Finishing formulation: citric acid (50 g/L); NaH_2PO_2·H2O (40 g/L); TiO_2-NPs Solution (20 g/L); wet pick up (80%); microwave fixation at 386 W/3 min., followed by one cycle after wash.
[b] WRA (W + F)°: wrinkle recovery angle (warp + weft).
[c] ZI: zone of inhibition, d UPF: UV-protection factor.

harmful UV-B radiation (Ibrahim, Amr et al., 2012; Ibrahim, Eid et al., 2012; Ibrahim, Eid, Hashem, El-Shafei, Refaie, & El-Hossamy, 2010) compared with the untreated ones and (vi) the extent of improvement in the UPF values is governed by type of the weave structure as discussed before.

Moreover, the data in Table 4 also demonstrated that exposure of the Basic Blue 9-stained/finished fabric samples to the daylight irradiation for 8 h results in a higher discoloration performance compared with the unfinished ones, irrespective of the used substrate, as a direct consequence of generation of highly oxidative free radicals such as $HO^{\bullet}$, and $HO^{\bullet}_2$ and their photo-catalytic degradation effect on the dye stains under the visible light irradiation (Bozzi, Yuranova, et al., 2005; Bozzi, Yuranova, Guasaquillo, et al., 2005; Qi et al., 2006; Ibrahim, Eid, et al. 2010;). On the other hand, the treated fabrics demonstrated a quite high functionality even after 10 washing cycles.

Additionally, both the SEM images and EDX spectra of plain (1/1) and satin (4) treated fabrics demonstrated in Fig. 3(e)–(h) confirm the presence of Ti-element onto the abovementioned substrates.

4. Conclusion

In this study, three weave structures of cotton/spandex blended fabric are successfully functionalized by easy care finishing in the presence of certain functional additives such as silicone-softener, water and oil repellent, Ag-NP′s and TiO_2-NP′s using the pad-microwave fixation technique. The extent of improvement in the imparted functional properties is governed by type of the weave structure and follows the decreasing order: Satin (4) >Twill (2/2) >Plain (1/1) regardless of the used functional finish. Bi-functional easy care/soft finish, easy care/water and oil repellence or easy care/antibacterial finish brings, about functionalized products with improved/durable effectiveness even after 10 washing cycles. Multifunctional finish using citric acid/NaH_2PO_2/TiO_2-NP′s results in imparted easy care/antibacterial/anti-UV/Self-cleaning durable functional properties to the treated substrates, regardless of the used fabric structure. Antibacterial activity against G+ve and G−ve bacteria follows the descending order: G+ve > G−ve, irrespective of the added nano-material. SEM and EDX analysis confirm the surface morphology modification; as in case of water/oil, Ag-NP′s, and TiO_2-loaded fabric samples, as well as the presence of Ag or Ti element onto the surface of the treated substrates.

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