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Eco-friendly Treatment on Rib Knitting Fabrics Part I. Enhancement of antimicrobial performance

L.K. El Gabry[1], Z.M. Abdel-Megied[2], H.M. Darwish[2] and A.S. El Geiheini[3]

[1]Protinic and Man-made fibres Department, [2]Clothing and Knitting Department, Textile Industrial Research Division, National Research Centre, 33 El-Buhouth St., (former El- Tahrir St.,) Dokki, Giza, Egypt, Postal Code: 12622.
[3]Facility of Engineering, Alexandria University, Egypt.

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ABSTRACT

This work is devoted to impart some new functional properties to kitted cotton fabrics. To achieve this purpose, knitted cotton fabrics containing Lycra (3%, 7%) are treated using various natural compounds namely; nanoclay (NC), β-cyclodextrin (CD), chitosan (CH) and citric acid (CA). Some physical and chemical properties of the treated as well as untreated cotton fabrics are evaluated such as moisture regain, bursting strength, abrasion resistant and fabric density number. FTIR of the treated and untreated cotton fabrics was investigated. The biocidal activity of the said fabrics was performed. The color intensity and fastness to wash of dyed fabrics with both direct and reactive dyes were determined. The results proved that the fabrics performance and comfort of the treated fabrics were enhanced compared to the untreated one.

Keywords: Knitted fabrics, natural material, antimicrobial activity, dyeing, fastness properties.

Introduction

Knitted fabrics have a good indicator and easily water vapor transfer from the body (Islam *et al.,* 2014). That's why knitted fabrics are commonly preferred for underwear, casual wear and sportswear (Oglakcioglu *et al.,* 2007). Knits also provide lightweight warmth, ease of care and wrinkle resistance (Chidambaram *et al.,* 2012). Strength determines the performance and durability of knitted fabrics. Bursting strength is length had a significant effect on the bursting strength, stitch density and fabric weight (Abd El-Hady, 2016). The outstanding of spandex are low moisture absorption, low resistance to exposure to sunlight and to most common chemicals (Byazit, 2003).

The cotton/polyester fabrics were tested with FAST system for assessing the garment performance (Fathy *et al.,* 2011). Treatment on viscose and its blend with polyester fibre with nano silica led to enhanced tear strength, performance properties and antibacterial activity (El-Gabry *et al.,* 2011 and El-Gabry *et al.,* 2013).

Cotton fibers treated with various chemicals, such as Cu O-chitosan, Silver nanoparticles nano composite, Triclosan and titanium dioxide for antibacterial treatment. It has strong biocidal effects on many pathogenic bacteria (Abou-Zeid *et al.,* 2011; Fulga Tanasa, 2014, and Slawson *et al.,* 1992).

Cotton fabrics were treated with chitosan hydrogel. The hydrogel-coated samples showed a clear improvement of the antibacterial activity with Gram-positive and Gram-negative bacteria. (Fayala *et al.,* 2015) Treated cotton fabric with chitosan give flame retardant. All chitosan treated fabric has grade 4 in soil release property as well as improved the crease recovery. (Edwin Sunder *et al.,* 2014).

The nano composites from mixtures of resin/nano clay with various percentages of nano clay were used on coated material (Elamri *et al.,* 2015). The flame retardant properties of cotton fabric enhanced with plasma treatments carried out by nano clay (Shahidi *et al.,* 20014). Nano/bio-finishing agent used to impact antibacterial activity, advanced softness and handle human dermal fibroblasts. (Maryan *et al.,* 2013) The treatment of denim garment with nano clay led to look garment with soft handle as well as enhanced both rubbing and thermal properties. This novel washing process was economical, easy a simple on the denim garment. The flammability nano coatings applied on textile

Corresponding Author: L. K. El Gabry, Textile Industrial Research Division, National Research Centre, 33 El-Buhouth St., (former El- Tahrir St.,) Dokki, Giza, Egypt, Postal Code: 12622.
E-mail: lamiaa_gabry@yahoo.com

fabrics using a continuous method as ideal industrial application. (Chin Chang *et al.,* 2014; Maryan et al., 20013). The development of some functional properties on viscose fabrics using nano kaolin were studied (Abou El-Kheir *et al.,* 2018).

Cotton fabric treated with cyclodextrins and triclosan enhanced the antibacterial activity. It was found that, the triclosan could be removed from cavities and the cavities were available (Cabrales *et al.,* 2012). The multifunctionalization of viscose fabric through loading with organic nanokaolin, nanochitosan and nanocellulose (El-Gabry *et al.,* 2018).

The aim of this study is to impart functional properties to select cotton knitted fabrics by using eco- natural material. The treatments with natural compounds such as Nano clay, chitosan, β-Cyclodextrin (CD) and Citric acid to impart antimicrobial properties as well as performance properties on cotton fabrics (Rib knitted containing 3% or 7 % Lycra). This study also illustrates the effect of treatment on dye ability and fastness properties. It will be studying the effect of treatments on the comfort and performance of treated fabric in part (2).

Material and Methods

Materials

Fabrics

Rib knitted cotton fabrics containing 3% and 7 % Lycra weight is 294 and 338 g/m^2 respectively. Natural materials such as Nano clay, chitosan, β- Cyclodextrin (CD) and Citric acid are used. β- Cyclodextrin (CD)were product of wacker- chemie GmbH, Germany. The nano clay (nanokaolin) used in this research was taken from National Research Centre Housing and Bulding. Figure 1 and 2 show nanokaolin and Chitosan respectively. Chitosan (Ch) from a crab shell (Mallinckrodt) were used. citric acid (CA) and acetic acid are of laboratory grade.

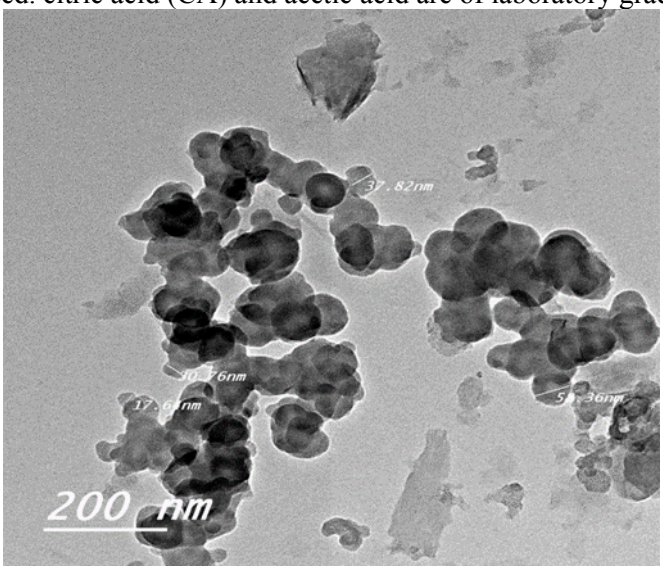

Fig. 1: TEM micrograph of Nanokaolin

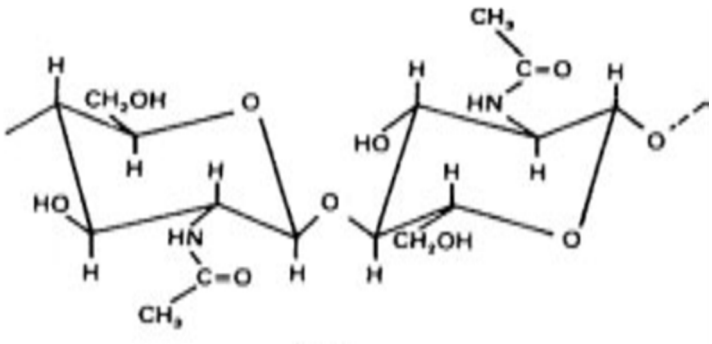

Fig. 2: The structure of Chitosan

Dyestuffs

Direct dyes (Solopneyl orange T4R) and Reactive dyes (Remazol Yellow GNL highly conc). is used. Figure 3 shows (C.I. Reactive yellow 4).

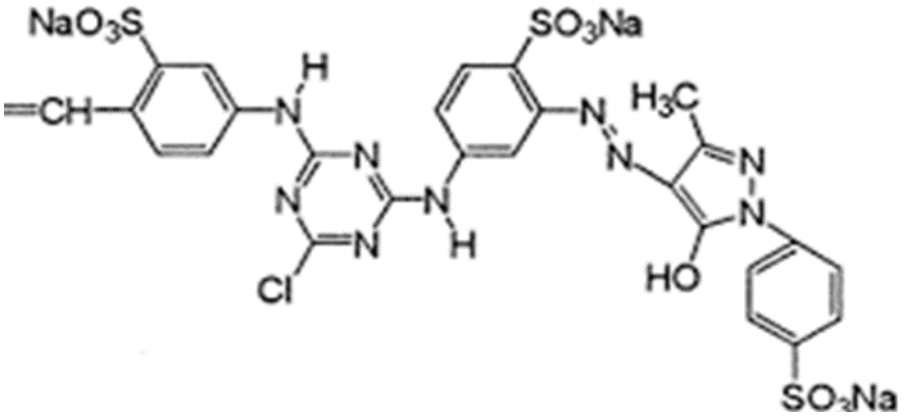

Fig. 3: C.I. Reactive yellow 4

Treatments

The two samples from Cotton fabrics contain Lycra plated were immersed in a solution containing 4g/l β- Cyclodextrin hydrate (CD). Other two samples were immersed in a solution containing 2.5g/l Nano clay as well as with both solutions 2g/l chitosan and 10g/l citric acid at room temperature for 1h, then padded to pick up 100 %, dried at 80°C for 10 min., and then fixed at 150°C for 5 min. Finally, the fabric is washed thoroughly with tap water and air dried.

Dyeing method

Dyeing with reactive dyes

The dye bath was prepared pasting shade (2% (o. w. f.)). The paste was then dissolved by adding hot boiling water. The dye solution was adjusted to pH 6 using acetic acid. The dye bath, C.I. Reactive yellow 4 (Remazol Yellow GNL highly conc.) was heated to 60 ºC and added the sample (cotton fibers) to the dye bath, the temperature was then raised gradually up to 90 ºC through 30 minutes then added 40 g/l sodium sulphate after 30 min., and the dyeing continued for 60 min., at liquor ratio 1:50. The dyed samples were withdrawn, rinsed with water and air dried

Dyeing with direct dyes

The dye solution of direct dyes (Solopneyl orange T4R) prepared by pasting (1 % o.w.f.). The dye bath completely to a liquor ratio of 50:1. The pH of dyeing bath was adjusted to be pH 6. The dyeing was started at 90 ºC after 20 min sodium chloride (10 g/L) was added to the dyeing bath and dyeing continue to 60 min. The dyed sample was thoroughly washed in water and air-dried.

Measurements

Different measured properties were determined under standard working conditions for fabrics under study before and after treatments by the following standards.

1- Moisture Regain measured according (ASTM – D2654).
2- Infrared Spectra recorded on FT-IR Nicolet 5 DX Spectrophotometer. The samples were examined as 1.5% KBr pellets.
3- Antibacterial Activity in Vito the two bacterial strains are applied and the antibacterial spectrum of the samples was determined against the test bacteria by disk diffusion method on an agar plate. (Munaza, 1994)
4- Color strength (intensity) K/S – (Judd D. and Wyszecki, 1975): Color intensity of the dyed fabric (k/s) was measured at the wave length of the maximum absorbance using a SF600+-CT Data colors spectrophotometer.

5- Washing fastness: The colorfastness to washing was determined according to the AATCC test method (AATCC Technical Manual, Method 36, (1972), 68, 23, (1993) using Lunder Ometer.

Results and discussion

The results obtained were statistically analyzed and discussed.

Moisture regain, abrasion resistance and thickness

Moisture regain %, relative increase % in moisture regains %, of treated and untreated cotton fabrics with (NC, CD, Ch, and CA) were shown in table 1. The results show moisture regain % of the treated fabrics increases than untreated one, the incensement in moisture regain reaches to 17% than untreated one. A significant increase with treatments with both CD and CA.

The significant increase in moisture regain may be may be attributed to hydrogen bonds formed between the said treated fabrics and water. CA was giving the best results which may referred to the -COOH groups of CA formed stronger hydrogen bonds with H_2O compered to Ch and CD.

Table 1: Moisture regain % of treated and untreated cotton (Rib knitted cotton fabrics)

Treated Sample With	Moisture Regain (%)		Relative Increase of Moisture Regain (%)	
Lycra %	3 %	7%	3%	7%
Untreated	4.24	4.22	-	-
Nano clay (NC)	4.85	4.82	14.2	14.21
β-Cyclodextrin (CD)	4.88	4.86	15.2	13.8
Chitosan (Ch)	4.69	4.67	11.7	10.7
Citric acid (CA)	4.9	4.9	17.9	16.1

Condition of treatments: Rib knitted cotton fabrics, (NC, CD, Ch, and SA), L: R, 1: 20, at room temp., for 1 hr., then padded to pick up 100 %, dried at 80°C for 10 min. and then fixed at 150°C for 5 min.

Colour strength and washing fastness

Table 2 shows the colour strength and washing fastness of untreated as well as treated Rib knitted cotton fabrics containing 7 % Lycra with both reactive and direct dyes. The treatment with nano clay led to higher increasement k/s value with reactive dye as compared with other treatments as well as untreated cotton fabrics. Also, it was found that nano clay enhanced the colour strength of dyed fabrics direct dyes, while the washing fastness of dyed fabrics was slightly affected. The treated fabrics with nano clay give higher colour strength than other treatments, this may be attributed to the chemical structure of nano clay which contain aluminum oxide and silicon oxide. It can be concluded from table 2 that all the treatments improved the k/s values of dyed fabrics compared to the untreated fabrics.

Table 2: Colour strength and washing fastness of treated and untreated cotton (Rib knitted cotton fabrics containing 7 % Lycra) dyed with reactive and direct dyes

Samples	Reactive dye				Direct dye			
		Washing fastness				Washing fastness		
	K/S lue	Alt	St_C	St_N	K/S vale	Alt	St_C	St_v
Untreated	2.49	3-4	4	4	6.49	4	4	4
Nano clay (NC)	7.58	4	4- 5	4	7.58	4	4-5	4
β- Cyclodextrin (CD)	2.92	4	4- 5	4	6.92	4	4-5	4
Chitosan (Ch)	2.02	3-4	4	4-5	7.02	4	4-5	4-5
Citric acid (CA)	2.08	3-4	4- 5	4-5	7.08	4	4-5	4-5

Condition of treatments: Rib knitted cotton fabrics containing 7 % Lycra, (NC, CD, Ch, and SA), L: R, 1: 20, at room temp., for 1hr., then padded to pick up 100 %, dried at 60°C for 10 min. and then fixed at 150°C for 5 min.

Dyeing condition: 2% (o. w. f.) C.I. Reactive yellow 4, at 90°C, added 40g/l sodium sulphate after 30 min., and the dyeing continued for 60 min., at liquor ratio 1:50.

Or: 1% (o. w. f.) C.I. Direct orange, at 90°C, for 1 hr., at liquor ratio 1:50.

Alt.: Alteration St_C = staining on cotton fabric St_v =staining on viscose fabric

St_N= staining on nylon fabrics

Fourier transform infrared spectra

Figure 4 shows the Fourier transform infrared spectra of treated and untreated cotton (Rib knitted cotton fabrics containing 7 % Lycra). The cod of the samples are the I for untreated fabric, II for treated fabric with nanoclay, III for treated fabric with β- Cyclodextrin, IV for treated fabric with chitosan, and V for treated fabric with citric acid. Thorough investigation of this figure reveals sharp medium peak at 3650.35-3290 cm^{-1} for stretching vibration of the O-H and N-H group. This peak overlapping in case of treatment cotton fabrics with nano clay, β- Cyclodextrin and chitosan (c.f. scheme II, III, V). The 1570 $cm^{-1,}$ 1412 cm^{-1} and 1302 cm^{-1} for C-H bending. Also, their new low peak was appeared at range of 520 and 430 cm^{-1} in sample II for Si-O. (Yang *et al.,* 2005). It was found that the week peak at 1578 cm^{-1} became strong peak with all treatments.

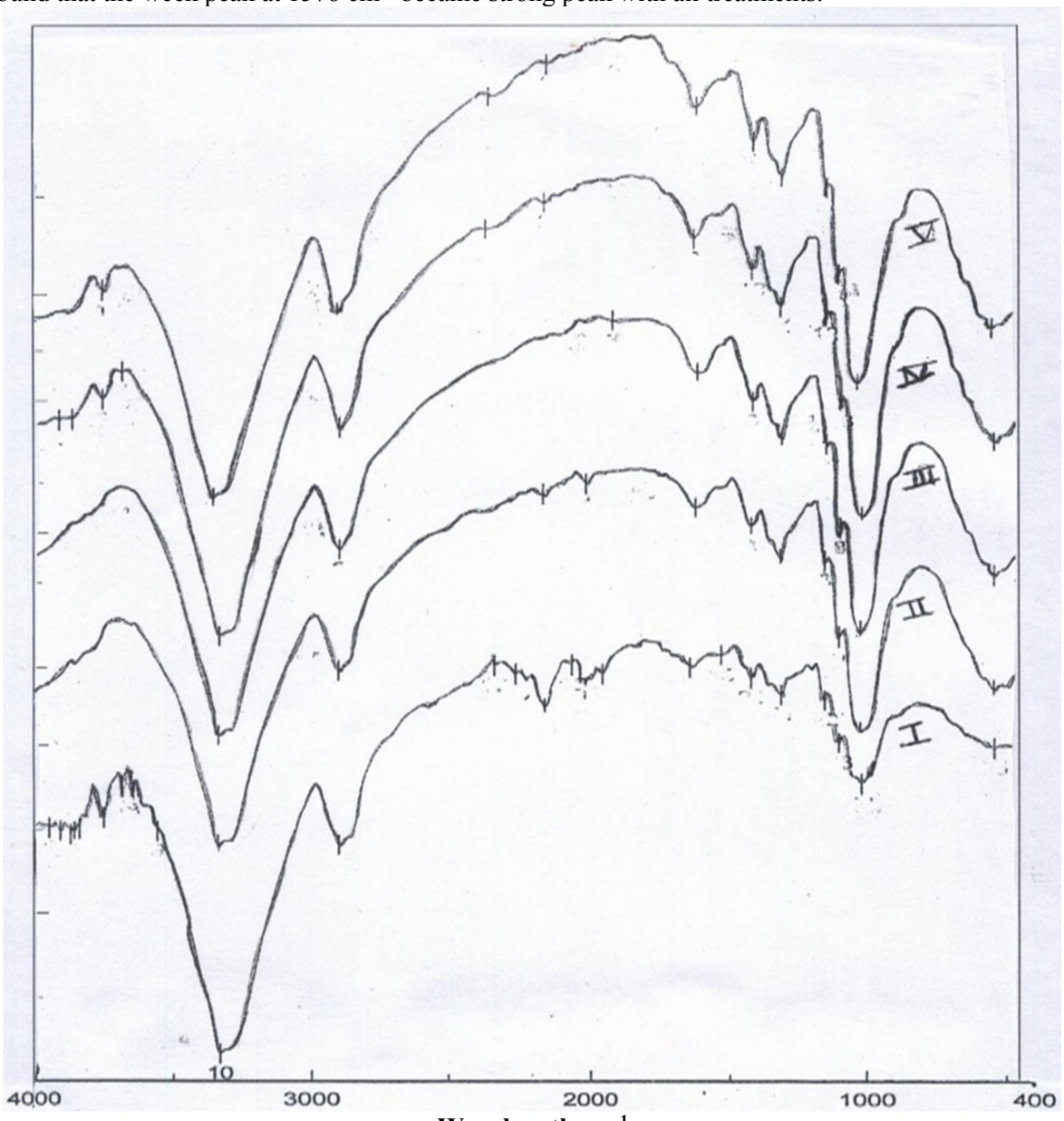

Fig. 4: Fourier transform infrared spectra of treated and untreated cotton (Rib knitted cotton fabrics containing 7 % Lycra) fabrics

Condition of treatments: Rib knitted cotton fabrics containing 7 % Lycra, (NC, CD, Ch, and SA), L: R, 1: 20, at room temp., for 1hr., then padded to pick up 100 %, dried at 60°C for 10 min. and then fixed at 150°C for 5 min.

I Untreated
II Treated with nano clay
III Treated with β- Cyclodextrin
IV Treated with chitosan
V Treated with silicic c acid

Antibacterial Activity

The antibacterial activity of the treated fabrics compared to the untreated one were measured. Data of table 3 show the effects of natural compounds used in the treatment of cotton fabrics on the inhibition zone for both gram negative and gram-positive bacteria namely; *Escherichia coli* and *Staphylococcus aurous* respectively. Data of table 3 revealed that the said compounds used in the treatment have a significant effect on the bacteria inhibition. Deep investigation of data tabulated in table 3 clarify that the highest inhibition zone was observes of the fabrics treated with citric acid followed by nanoclay then chitosan and β-cyclodextrin. This may be attributed to the presence of -COOH groups of citric acid, metal oxides in nanoclay, $-NH_2$ groups of chitosan and antibacterial property of β-cyclodextrin (Maryan, 2013)

Table 3: Antibacterial Activity of Untreated and Treated cotton (Rib knitted cotton fabrics containing 7 % Lycra) fabric

Samples	Inhibition Zone Diameter (mm/1 cm sample)	
	Escherichia coli (G-)	Staphylococcus aureus (G-)
Untreated	1.5	0
Nano clay (NC)	16.5	15.5
β- Cyclodextrin (CD)	13	9.5
Chitosan (Ch)	15	15
Citric acid (SA)	18	17

Condition of treatments: Rib knitted cotton fabrics containing 7 % Lycra, (NC, CD, Ch, and SA), L: R, 1: 20, at room temp., for 1hr., then padded to pick up 100 %, dried at 60°C for 10 min. and then fixed at 150°C for 5 min.

Conclusion

From the previous results the following can be stated:

1- The applied treatments increase the moisture regain which ameliorate the colour strength and the washing fastness.
2- The citric acid tends to better results in moisture regain and antimicrobial activetyfollowed by the citric acid, while the other two treatments gave the lower improvements.
3- The applied natural materials have generally significant effect on the tested properties. Also, the antibacterial activities were observed with the treated cotton knitted fabrics. The nano clay and citric acid demonstrate almost the better results.

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