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Combined Antimicrobial Finishing Dyeing Properties of Cotton, Polyester Fabrics and Their Blends with Acid and Disperse Dyes

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THIS STUDY demonstrates the possibility of enhancing the antibacterial activity and dyeing properties of cotton, polyester and their blended fabrics in one step. These fabrics were treated first with carboxymethyl chitosan to impart its antibacterial activity and enhance dye ability at the same time followed by dyeing with acid dyes and disperse dye. Results show an improvement in antibacterial activity and dye ability. It was further noted that, in all cases, the treated fabrics were more susceptible towards Gram positive bacteria (*S. aureus*) than Gram negative bacteria (*E. coli*) due to bacteria structure. The treated samples exhibited very sufficient antibacterial activity even after 25 washing cycles through durability test. modification was also confirmed by FT-IR and TGA.

Keywords: Carboxymethyl chitosan antimicrobial finishing, Dyeing properties, Cotton, polyester, Cotton/polyester blends, Acid dye and disperse dye.

Introduction

Among the various functional finishes, high attention has given to the textile materials that are bioactive, to cope with the growing awareness of health and quality of hygiene, without adversely affecting their traditional characteristics using different antimicrobial agents. The available antimicrobial agents differ in their chemical structure, antibacterial activity, application method, mode of interaction as well as environmental impact [1-3].

The most promising antimicrobial agents currently available for textile application include: inorganic compounds such as metal salts, nano-sized metals and metal oxides, halogenated phenols, N-halamines, quaternary ammonium compounds, chitosan ,neem oil, antibiotics and immobilized enzymes [1, 3-8].

The use of chitosan and its derivatives in textile field has increased rapidly to develop efficient, non-toxic, biocompatibility, biodegradable and cost effective functionalized textiles with multifunctional properties and increased potential applications [8].

Chitin, polymer of N-acetyl glucose amine, is the second most abundant polysaccharide next to cellulose. It occurs in crustacean. Chitosan is a deacetylated chitin is a copolymer of glucose amine and N- Acetyl glucose amine. Chitosan has unique properties from its compatibility, biodegradability in addition it is safe materials which promise its uses in several fields as wound dressing, wound healing, antibacterial, antioxidant, water and blood filtration [9-12].

Chitosan is insoluble in organic solvents, it is soluble in weak acids only so that we can used carboxymethyl chitosan as water soluble derivative instead of chitosan itself as antibacterial material in biological, biomedical and water filtration applications [13]..

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Chitosan and its derivatives accelerate bacterial cell aggregation and bacterial call wall membrane disorganization causing loss of cellular fluids and bacterial death. Therefore chitosan used as antibacterial textile finishing agent, antitumor and biomedical applications [14-16].

The main goal of the current research is to develop a new and effective dyeing method for enhancing the antibacterial activity of dyed cotton, polyester, cotton/polyester blended fabrics via treatment with carboxymethyl chitosan followed by dyeing process. The colorimetric properties were assessment to follow the dyeing enhancement and disk inhibition zone evaluated to follow the antibacterial activity.

Experimental

Materials

Chitosan (CS) (Aldrich, viscosity 1860cps, degree of deacetylation 79.0%). Sodium hydroxide (Modern Lab chemicals), monochloroacetic (Fluka), are used without further purification. Four bacterial other chemicals and reagents were of analytical grade, and were used without further purification.

Two bacterial strains from the Faculty of women for Art, Science & Education, Ain Shams University, Cairo, Egypt were employed. They include Gram-positive (G +ve) bacteria: Staphylococcus aureus (S. aureus) and the Gram-negative (G−ve) bacteria: Escherichia coli (E. coli). These bacterial strains were selected as test cells because they are the most frequent bacteria in the wound infection and represent Gram positive and Gram-negative bacteria, respectively. Fresh inoculants for antibacterial assessment were prepared on nutrient broth at 37°C for 24 hours.

Scoured and bleached cotton 100%, polyester 100, cotton/polyester (50/50), cotton/polyester (45/55), cotton/polyester (55/45), cotton/polyester (20/80) blended fabrics were used.

Arkofix® NDF liq. C (low content of free formaldehyde, based on modified N-methylol dihydroxy ethylene urea, DMDHEU, Clariant), Astroglitter binder® based on, nonionic/ anionic acrylic resin compound, citric acid, sodium hypophosphite, and Hostapal® CVL-ET (nonionic wetting agent based on alkyl aryl polyglycol ether, Clariant)

Acid dye® (1:2 metal complex) Sunset Blue PA, (C.I. Acid Blue 317), Single azo, OHYOUNG INDUSTRIAL CO., LTD.

Disperse dye® (low energy) Suncron E Red E-FB 200% (C. I. Disperse Red 60, C.I. 60756), anthraquinones, OHYOUNG INDUSTRIAL CO., LTD.

Carboxymethylation of chitosan

The carboxymethylation of chitosan (CMCS) was prepared as reported in our previous work [17] as follow; chitosan (5g), sodium hydroxide (50%), isopropanol (80ml), and water (20ml) were added into a three necked flask (250ml) to swell and alkaline at room temperature for one hour. The monochloroacetic acid (2.5M) was dissolved in isopropanol (20ml), and added into the reaction mixture drop wise for 30 minutes and reacted for proper time (3 hrs) at temperature (60°C), then stopped by adding 80% ethyl alcohol. The solid was filtered and rinsed in 70-90% ethyl alcohol to desalt and dewater and dried at room temperature.

Fabric Treatment

The fabric such as cotton 100%, polyester 100, cotton/polyester (50/50), cotton/polyester (45/55), cotton/polyester (55/45), cotton/polyester (20/80) blended fabrics were padded two dips and nips (90–95% wet pick up) in a solution containing carboxymethyl chitosan with different concentrations (1%-3%-5%-7%), 100 g/L acrylate binder, 50 g/L Arkofix, 45 g/L citric acid as crosslinking, and without crosslinking, 25 g/l sodium hypophosphite as a catalyst, 2 g/L non-ionic wetting agent liquor ratio 1: 20. After treatment, all the fabrics were dried at 100 °C for 5 min and cured at 160 °C for 3 min.

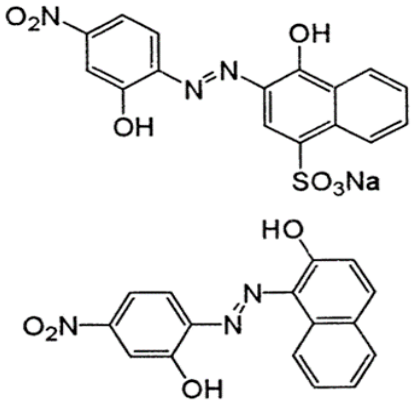

Fig. 1. Chemical structure of Sunset Blue PA.

Fabric Dyeing Procedures

All the fabrics were treated with carboxymethyl chitosan and untreated fabrics were dyed using, disperse, and acid dyes.

Acid dye

Sunset Blue PA (C.I. Acid Blue 317), Single azo, 1: 2 Metal Complexes, OHYOUNG INDUSTRIAL CO., LTD.

A dyeing bath solution containing 5% dye (o.

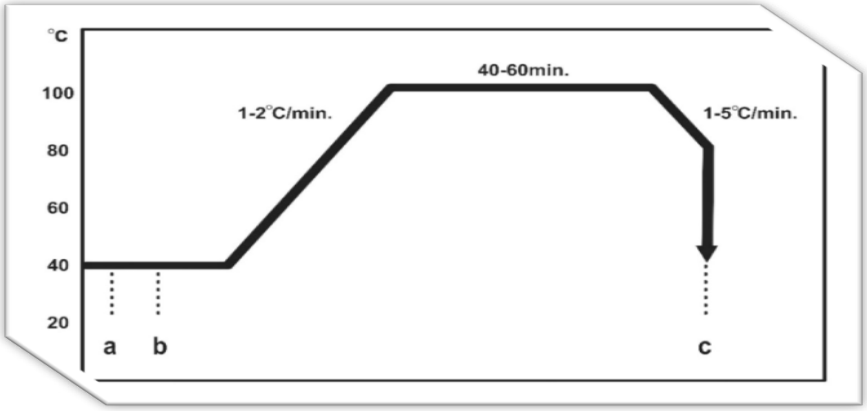

Fig. 2. Dyeing curve¬ of Acid dye.

A: Levelling agent; 0.5-2.0%, PH 3-6, B: Dye & C: Drain and Rinse.

w. f), and acetic acid with concentration 5% were used. The dyeing process started at 40 °C and raised to 100 °C through 30 min and the dyeing was performed at 100 °C for 40-60 min using material-

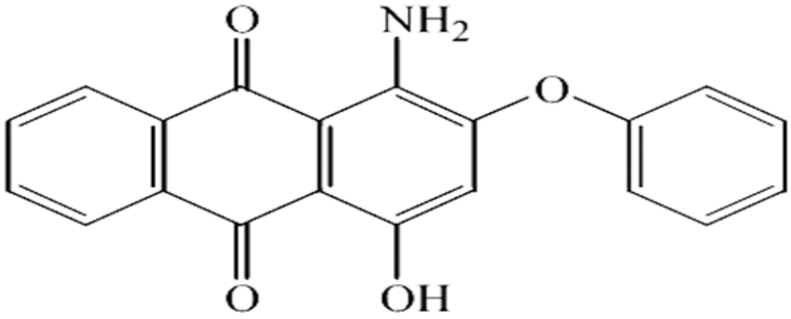

Fig. 3.Chemical structure of Suncron E Red E-FB 200%.

to-liquor ratio 1:50. After dyeing, the fabrics were thoroughly washed with 1-5 g/L of non-ionic detergent for 30 min at 60 °C and then washed with cold water. The dyed fabrics were dried.

Disperse dye

Suncron E Red E-FB 200% (C. I. Disperse Red 60, C.I. 60756), anthraquinones, OHYOUNG INDUSTRIAL CO., LTD.

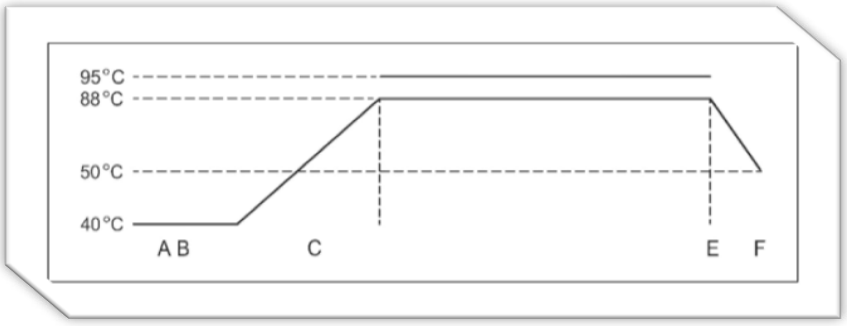

Fig. 4. Dyeing curve of Disperse dye.

A: Auxiliaries	Anionic levelling agent.
B: Dye	X % o. w. f., PH 3.0-6.0.
C: Temperature raise	1.0-2.0 °C/min.
D: Dyeing time	30 to 60 min. at 80-100 °C.
E: Cooling	2.0 °C/min.
F: Soaping	50 °C/10 min.

A dyeing bath solution containing 5% dye (o. w. f), Anionic or Nonionic levelling agent, dispersing agent, carrier, and acetic acid with concentration 5% were used. The dyeing process started at 40 °C and raised to 100 °C through 30 min and the dyeing was performed at 100 °C for 30-60 min using material-to-liquor ratio 1:50. After dyeing, the fabrics were thoroughly washed with 1-5 g/L of non-ionic detergent for 10 min at 95 °C and then washed with cold water. The dyed fabrics were dried.

Measurements and Testing

Nitrogen content was determined using micro- Kehjeldal Procedure [18]. Thermo gravimetric analysis (TGA) was performed at a temperature starting from 25 °C to 600 °C under inert nitrogen atmosphere with heating rate of 10 °C min-1 using the instrument: SDT Q600 V20.9 Build 20, USA .Fourier transforms infrared spectra (FTIR) measured at a JASCO FT-IR-6100 spectrophotometer using the KBr pellet disk method for transmittance measurements. The surface morphology of untreated and treated cotton fabrics were obtained by using Scanning electron microscope (SEM) images, 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, FEI company, Netherlands. The disc diffusion method [19] was used for assessing the antibacterial activity of CMCS powder, untreated and treated cotton fabrics. Briefly, discs of 10 mm diameter were cut from the cotton fabrics. Nutrient agar plates were incubated with microbial culture. The cut discs of untreated and treated cotton fabrics were placed onto the surface of inoculated plates. The plates were incubated at 37oC for 48 hours. The inhabitation zone (distance from disc circumference in mm) was determined for each disc. Color strength of the obtained dyeing, expressed as K/S values, was calculated from reflectance data using Kubelka-Munk equation [20]: $K/S = (1-R)^2/2R$ where K and S are the absorption and scattering coefficient respectively, and R is the reflectance at wavelength of maximum absorbance of the used pigment colorants.

Results and Discussion

IR analysis of carboxymethylation of chitosan:

Based on our previous work we prepare carboxymethyl chitosan via reaction of chitosan with monochloroacetic acid in the presence of sodium hydroxide for 3hrs at 60 °C [17]. The FTIR spectra of all the O-CMCSs prepared in this study were similar, and an example is shown in Figure 5. In these spectra, the wide band at 3420 cm^{-1} corresponds to the axial stretching of the O–H and N–H bonds. The peaks at 2927 cm^{-1} and 1639 cm^{-1} are attributed to the axial stretching of the C–H bonds and the symmetric stretching vibration of C=O in the –COOH groups, respectively. The latter peak, together with the peak at 1420 cm^{-1}, which arose from the asymmetric stretching vibration of the $–COO^–$ group, confirm the substitution of carboxymethyl groups onto the chitosan chain. Two bands at 1528 and 1513 cm^{-1} assigned to NH_3^+, indicate that the Carboxymethylation occurred at OH positions The peaks at 1413 and 1377 cm^{-1} are related to the symmetric angular deformation of C–H bonds and C– N stretching vibrations (amide

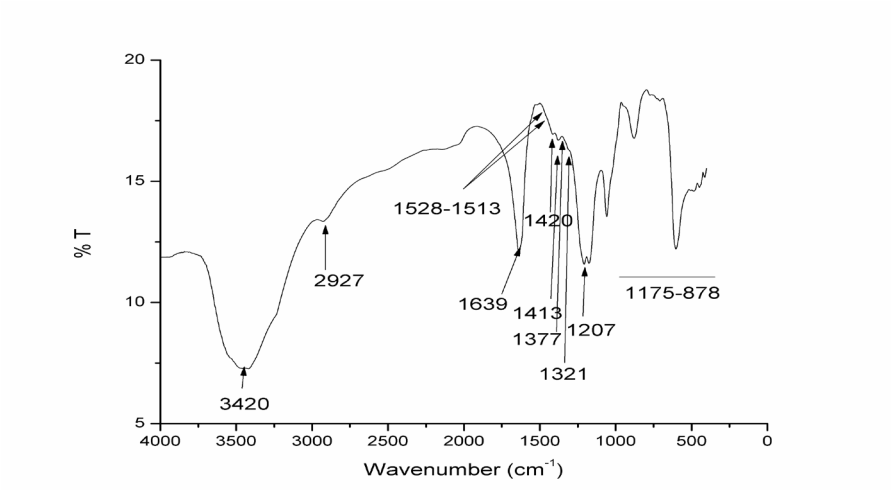

Fig. 5. FTIR spectrum of the CMCS prepared by reaction of 5 gm chitosan with 2.5 M MCAA in the presence of 50% NaOH within 3 hr at 60 °C

III band), respectively The peak at 1377 cm^{-1} did not increase significantly in the spectra of the O-CMCSs, compared to the chitosan spectrum, which indicates that a significant amount of N-carboxymethylation did not take place The stretching vibration of C–O in the CH_2COOH group gives rise to the peak at 1207 cm^{-1}. Peaks located in the range of 1175-878 cm^{-1} are the result of vibrations of C–O and C–O–C and some other bonds that comprise the polysaccharide chain

Pretreatment of polyester/cotton blend fabrics

The fabrics were first pretreatment with the prepared carboxymethyl chitosan with different concentration (1-7%) gm/100ml; to improve both antibacterial and dyeing properties.

One-bath dyeing of polyester and cotton fabrics and their blends:

Polyester and cotton fabrics and their blends were dyed together in the same dye bath to investigate the dyeing behaviour of acid and disperse dyes on each component.

Colorimetric properties of the fabrics:

The colorimetric CIE L*a*b*C*h^{o} *ΔE data of the dyed fabrics was pretreated using acid dye and disperse dye are shown in **Tables 1 and 2** respectively and the colorimetric CIE whiteness and yellowness data of the undyed cotton fabric are shown in **Table 3.** The colour parameters were evaluated by means of the Cielab system and the

TABLE 1. Colorimetric data of the dyed Cotton fabrics was pretreated using acid dye (5% w. o. f) at 100 °C at wave length 600 nm.

Fabric	Cross Linking	CMCS; %	K/S	L*	a*	b*	C*	h^{o}	ΔE
cotton	Without treatment	0	1.54	56.32	- 1.65	- 11.21	11.35	261.62	0.02
	Without crosslinking	1	2.77	48	-2.22	-12.08	12.28	259.58	8.38
		3	2.93	47.14	-2.2	-12.15	12.35	259.75	9.24
		5	3.28	45.59	-2.21	-12.41	12.6	259.9	10.81
		7	3.45	44.81	-2.13	-12.29	12.47	260.15	11.58
	Acrylate binder	1	3.58	44.3	-2.58	-11.45	11.73	257.3	12.06
		3	3.66	43.97	-2.5	-11.73	12	257.98	12.4
		5	6.51	35.66	-2.07	-11.51	11.7	259.82	20.67
		7	7.49	33.82	-2.2	-11.49	11.7	259.13	22.51
	Arkofix	1	2.12	51.73	-2.08	-11.51	11.7	259.78	4.62
		3	2.22	51.15	-1.99	-11.82	11.99	260.45	5.22
		5	2.44	49.72	-2.14	-11.87	12.06	259.77	6.65
		7	5.18	39.42	-2.23	-13.52	13.7	260.62	17.07
	Citric acid	1	2.62	48.81	-2.16	-12.03	12.23	259.82	7.57
		3	3.18	46.29	-2.35	-12.8	13.02	259.59	10.19
		5	5.7	37.78	-2.09	-13.25	13.42	261.02	18.66
		7	6.01	37.5	-2.21	-13.72	13.89	260.85	19

modified CIE L* C * h° (D65/10°) system. The following colour parameters for the dyed samples were obtained by the digital Cielab system: L* – lightness, a* – redness if positive coordinate, or greenness if negative coordinate, b* – yellowness if positive coordinate, or blueness if negative coordinate.

Colorimetric data of the dyed fabrics with Acid dye

Table 1 showed an improvement of the colorimetric data (expressed in K/S values) of the treated samples with O-CMCS than that of the untreated ones for dyeing with acid dye. In addition, the concentration of O-CMCS plays an important role in this improvement whereas the K/S vales increased as the O-CMCS percent increased. Also the colorimetric data shows the dependence of these enhancements on the cross linker used (its chemical structure); the K/S values increased as follow:

- Without crosslinking < Arkofix < Citric acid < Acrylate binder (cotton 100% fabric).
- Arkofix < Without crosslinking < citric acid < Acrylate binder (Polyester 100% fabric).
- Arkofix < citric acid < Without crosslinking < Acrylate binder (Cotton / Polyester (20/80) fabrics).
- Arkofix < Without crosslinking < Citric acid < Acrylate binder (Cotton / Polyester (45/55) fabrics).
- Citric acid < Without crosslinking < Acrylate binder < Arkofix (Cotton / Polyester (50/50) fabrics).
- Arkofix < Citric acid < Without crosslinking < Acrylate binder (Cotton / Polyester (55/45) fabrics).

TABLE 2. Colorimetric data of the dyed cotton fabric was pretreated using disperse dye (5% w. o. f) at, 95 °C at wave length 525 nm.

Fabric	Cross Linking	CMCS; %	K/S	L*	a*	b*	C*	h°	ΔE
cotton	Without treatment	0	0.94	64.48	19.80	- 6.91	20.98	340.75	0.01
	Without crosslinking	1	0.91	65.16	19.62	-6.1	20.55	342.73	1.09
		3	0.99	64.22	20.57	-6.8	21.66	341.71	0.82
		5	1.01	63.58	20.22	-5.78	21.03	344.05	1.52
		7	1.07	63.48	22.21	-7.02	23.29	342.46	2.61
	Acrylate binder	1	6.75	39.7	36.5	-0.14	36.5	359.78	30.64
		3	7.51	38.11	36.61	1.18	36.63	1.85	32.31
		5	8.57	36.76	37.56	2.1	37.62	3.2	34.14
		7	8.9	36.14	37.51	2.34	37.58	3.56	34.68
	Arkofix	1	0.93	65.22	20.87	-7.39	22.14	340.51	1.38
		3	0.94	64.75	20.2	-6.56	21.24	342.01	0.61
		5	1.01	63.59	20.34	-6.13	21.25	343.22	1.31
		7	1.04	63.34	21.07	-6.23	21.97	343.52	1.84
	Citric acid	1	1.3	61.24	24	-7.7	25.21	342.21	5.36
		3	1.31	60.96	23.99	-7.95	25.27	341.68	5.57
		5	1.32	60.66	23.33	-7.41	24.48	342.37	5.22
		7	1.35	60.11	22.87	-7.29	24	342.33	5.35

From these results we can find that the dyeing properties depends on both CMCS as treatment material, crosslinking agent used and the fabrics structure and reflect the relationship between them represented in K/S values.

Colorimetric data of the dyed fabrics with Disperse dye

Also, Table 2 shows similar trend like that for fabrics dyed with acid dyes as follow:

- Arkofix < Without crosslinking < Citric acid < Acrylate binder (Cotton 100% fabrics).
- Without crosslinking < Citric acid < Arkofix < Acrylate binder (Polyester 100% fabrics).
- Without crosslinking < citric acid < Arkofix < Acrylate binder (Cotton / Polyester (20/80) fabrics).
- Arkofix < citric acid < Without crosslinking < Acrylate binder (Cotton / Polyester (45/55) fabrics).

TABLE 3. Whiteness and yellowness of the finished fabrics.

Fabric	Crosslinking	CMCS; %	WI	YI
cotton	Without treatment	0	-201.56	191.63
	Without crosslinking	1	-204.07	193.09
		3	-205.58	193.46
		5	-207.88	194.42
		7	-209.29	195.95
	Acrylate binder	1	-196.57	189.97
		3	-198.15	188.73
		5	-201.08	191.15
		7	-206.42	194.02
	Arkofix	1	-203.79	193.16
		3	-204.25	192.79
		5	-205.39	192.84
		7	-205.81	193.6
	Citric acid	1	-205.39	194.07
		3	-205.75	194.52
		5	-208.48	194.81
		7	-218.89	199.24

- Arkofix < Without crosslinking < Citric acid < Acrylate binder (Cotton / Polyester (50/50) fabrics).
- Without crosslinking < Arkofix < Citric acid < Acrylate binder (Cotton / Polyester (55/45) fabrics).

Whiteness and yellowness of the finished fabrics:

From Tables 3 we found that the treated samples with O-CMCS shown an improvement of yellowness values than that for the untreated samples.

Carboxymethyl chitosan plays an important role in the increment of the yellowness values; whereas as O-CMCS concentration increased caused decreased in whiteness values and increased

in yellowness values of these fabrics; i.e. the WI vales decreased and YI increased as the CMCS percent increased. This is due to introducing amino groups of O-carboxymethyl chitosan and the chitosan natural coloration that appears yellowish to some extent increase yellowness as the concentration of O-carboxymethyl chitosan increased [20].

In addition, the colorimetric data shows the dependence of these enhancements on the crosslinking agent used (its chemical structure); the YI values increased as follow:

- Arkofix < Acrylate binder <Without crosslinking < Citric acid (Cotton 100% fabric).
- Without crosslinking < Acrylate binder < Arkofix < Citric acid (Polyester 100% fabric).
- Acrylate binder < Without crosslinking < Citric acid < Arkofix (cotton / polyester (20/80) fabric).
- Acrylate binder < Without crosslinking < Citric acid < Arkofix (cotton / polyester (45/55) fabric).
- Acrylate binder < Without crosslinking < Citric acid < Arkofix (cotton / polyester (50/50) fabric).

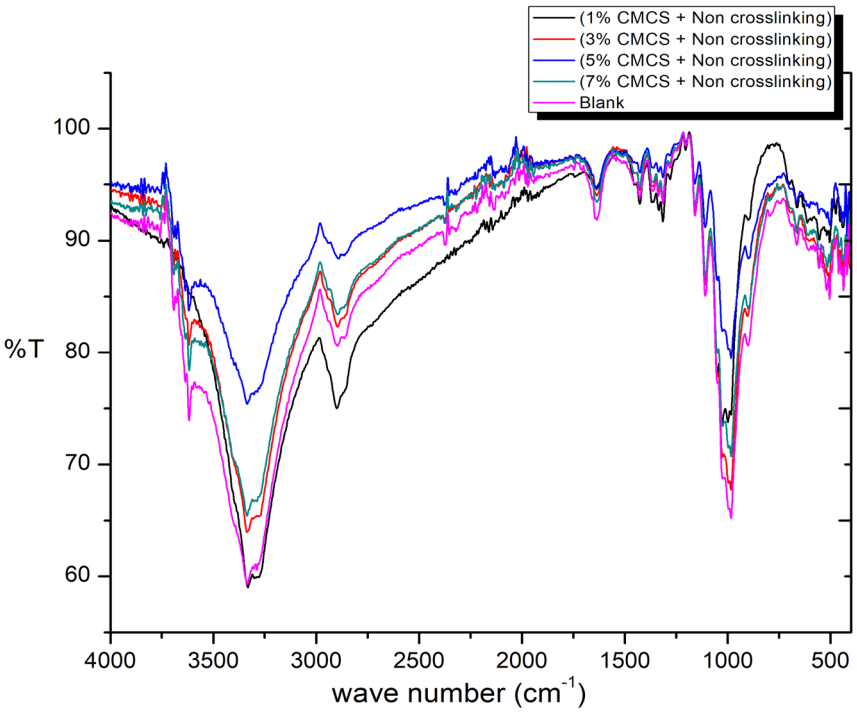

Fig. 6. IR data of the dyed cotton fabric with acid dye was pretreated with concentration of carboxymethyl chitosan (1%, 3%, 5%, 7%) without crosslinking

- Acrylate binder < Without crosslinking < Citric acid < Arkofix (cotton / polyester (55/45) fabric).

From these results we can find that the change in colour depend on both O-CMCS as treatment material, crosslinking agent used and the fabrics structure.

IR data of undyed and dyed fabrics

It is clear from IR spectra that there is effect of dyeing compared with undyed samples are appeared; where the broad band for CMCS at 3300 cm^{-1} replaced by sharper one with some type of chemical shifting. All dyed samples as similar and different in the intensity only as shown in these figures. In addition, we can find that the crosslinking agent affect also on the band intensity of the dyed samples

Thermal Analysis (TGA)

Thermal stability of the untreated and treated fabric with chitosan evaluated based on thermo gravimetric analysis (TGA). Figure 7 shows the TGA evaluations expressed on weight loss % with temperature for untreated and treated fabric with CMCS which show similar behavior with four main thermal degradation stages. It can

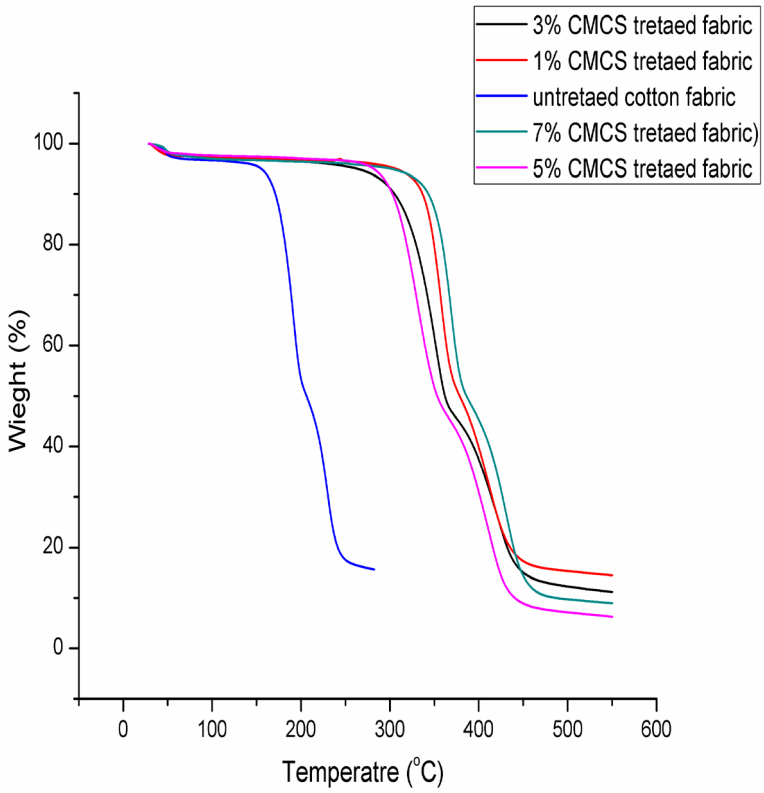

Fig. 7. TGA Data for untreated cotton fabrics and the treated one with different concentration of carboxymethyl chitosan.

be observed from TGA data that there is great enhancement in thermal stability for the treated samples where the untreated fabric completely decomposed with three main stages start from 200 °C till 292 °C, but the treated one show these three main stages but start at 345 °C then at 440 °C and ended at 562 °C. this enhancement due to the presence of amino groups beside carboxyl groups in carboxymethyl chitosan.

Antibacterial Activity of treated CMC Fabrics:

For assessment of antibacterial activity, treated samples subjected to disk diffusion test method. The effect of carboxymethyl chitosan concentration, fabric type and crosslinking agents on antibacterial activity studied and the results are listed in Table 4. The zone of inhibition (diameter) was recorded in each case. The results of untreated samples show clear growth of bacteria under them with no zone of inhibition, indicating that the untreated and undyed fabric by itself does not inhibit bacterial activity. The investigated treated samples inhibit bacterial growth as is evident from the absence of growth under all undyed samples. It was observed that the carboxymethyl chitosan shows antibacterial activity on both Gram positive and Gram negative bacteria, metal salt has more effective inhibition on *S. aureus* than *E. coli* [20, 21]. Due to their different cell walls. S. aureus, a typical Gram-positive bacterium, its cell wall is fully composed of peptide poly glycogen, which allow foreign molecules to come into the cell without difficulty. But, the cell wall of E. coli, a typical Gram-negative bacterium outer membrane constituted of lipopolysaccharide, lipoprotein and phospholipids, and has potential barrier against foreign molecules [20].

All treated fabrics (cotton, PE and their blends) show high antibacterial activity towards both Gram positive and Gram negative bacterial and the antibacterial activity increased as the carboxymethyl chitosan increased

In addition, from Table 4 we found that these

TABLE 4. Antibacterial activity and nitrogen content of treated cotton Fabrics.

Fabric	Crosslinking	CMCS; %	%N	One washing cycle ZI (mm)		25 washing cycle ZI (mm)	
				S. aureus	S. aureus	E.coli	S. aureus
cotton	Without crosslinking	1	0.05%	1.5	0.5	1.0	0.5
		3	0.20%	6	4.5	5.0	4.0
		5	0.21%	10.5	8.5	9.0	7.0
		7	0.30%	16.5	15	15.5	14
	Acrylate binder	1	0.39%	0.5	1.0	0.5	1.0
		3	0.51%	6	3.5	4.5	2.5
		5	0.59%	13	10	12	9.0
		7	0.61%	22	18	20.5	16.5
	Arkofix	1	0.52%	2.0	2.0	2.0	2.0
		3	0.66%	7.0	5.5	7.0	5.5
		5	0.75%	13	10.5	13	10.5
		7	0.91%	17	15	17	15
	Citric acid	1	0.14%	0	0	0	0
		3	0.19%	3	2	3	2
		5	0.29%	11	8.5	11	8.5
		7	0.41%	16	14.5	16	14.5

Zone of inhibition (diameter in mm)

treated fabrics show antibacterial activity ranged from good to excellent even after 25 washing cycles. so that these fabrics are durable through further approval.

We used commercial dyes, which has no antibacterial properties so that we did not need to perform antibacterial activity test for dyed samples

Conclusion

In this work inclusion of acid and disperse dyes with antibacterial finish auxiliaries into a single dyeing process to get high quality cotton/polyester dyed remarkable antibacterial functionality were investigated. Higher color strength values along with a better antibacterial activity are obtained in the case of using carboxymethyl chitosan (7gm/100ml) followed by dyeing with acid or disperse dyes at recorded conditions. The extent of improvement in the dye ability and antibacterial performance properties is governed by the concentration of carboxymethyl chitosan as antibacterial agent, type of crosslinking and dyes used as well as the content of cotton cellulose in the blended substrates. After 25 wash cycles, the obtained dyed fabrics still had a remarkable antibacterial function along with noticeable color retention and soft handle. The observed combined process can be easily adapted on industrial scale.

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خواص مقاومه البكتريا والصباغة من الأقمشة القطنية والبوليستر ومزيجها مع الأصباغ الحمضية والمشتتة

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ازداد استخدام الكيتوزان ومشتقاته في مجال النسيج بسرعة لتطوير منسوجات فعالة وغير سامة وذات توافق بيولوجى وقابلة للتحلل حيويا وفعالة من حيث التكلفة مع خصائص متعددة الوظائف وتطبيقات محتملة متزايدة. توضح هذه الدراسة إمكانية تحسين النشاط المضاد للبكتيريا وخصائص صباغه القطن والبوليستر والأقمشة المخلوطة في خطوة واحدة. تمت معالجه هذه الأقمشة باستخدام كربوكسى ميثيل الكيتوزان لإكسابها مقامه عالية ضد البكتريا وتحسن قابليتها للصباغة في نفس الوقت ويلي ذلك صباغه تلك الأقمشة بالصبغات الحامضية والمشتتة. هذا وقد أظهرت النتائج تحسن ملحوظ في كل من مقاومه البكتريا وقابليه الصباغة. ولوحظ كذلك، في جميع الحالات، أن الأقمشة المعالجة أظهرت مقاومه للبكتيريا موجبه بالنسبة لصبغه جراهام (*S. aureus*) أكثر من البكتيريا سالبة الجرام (*E. coli*) ويرجع ذلك الى تركيب البكتيريا. يخضع مدى التحسن في قدرة الصبغة وخصائص الأداء المضادة للبكتيريا الي تركيز كربوكسى ميثيل الكيتوزان كعامل مضاد للبكتيريا، ونوع التشابك والصبغات المستخدمة وكذلك محتوى سليلوز القطن في الأقمشة المخلوطة. بعد 25 دورة غسيل، كانت الأقمشة المصبوغة التي تم الحصول عليها لا تزال لديها وظيفة مضادة للجراثيم رائعة مع احتفاظ ملحوظ باللون وملمس ناعم. يمكن تكييف العملية المدمجة المرصودة بسهولة على نطاق صناعي. وتم استخدام كل من طيف الأشعة تحت الحمراء والتحليل الحراري لأثبات ذلك التعديل الحادث.