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Multifunctional properties of cotton fabric treated with chitosan and carboxymethyl chitosan

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Abstract

A water soluble carboxymethyl derivative of chitosan was prepared with a view to develop a multifunctional finish on cotton. Results show that treated cotton has better dyeability with direct and reactive dyes. Treatment with modified chitosan makes it possible to dye cotton in bright shades with cationic dyes having high wash fastness. Treated samples showed good antimicrobial activity against *Escherichia coli* and *Staphylococcus aureus* at 0.1% concentration as well as improved wrinkle recovery. The effect was found to be durable for five laundering cycles.

Keywords: Antibacterial activity; Chitosan; Basic dyeable cotton; Multifunctional finish

1. Introduction

Chitosan is a partially deacetylated polymer of acetyl glucosamine obtained after alkaline deacetylation of chitin (Kurita, 1998). It comprises copolymers of glucosamine and *N*-acetyl glucosamine (Sanford, 1989; Illum, 1998; Mishra, Jayanth, & Sankar, 2003) and has a combination of many unique properties, such as non-toxicity, biocompatibility and biodegradability (Li, Dunn, Grandmaison, & Goosen, 1997; Illum, 1998; Singla & Chawla, 2001).

Chitosan has got wide application in textile dyeing and finishing as a substitute for the various chemicals used in textile processing (Lim & Hudson, 2003). It has been used as a pretreatment agent in dyeing of cotton, in textile printing, wool dyeing and shrink proofing and in durable press finish. However, the application of chitosan in textiles is limited due to its poor solubility above pH $\sim$ 6.5 (pK_a $\sim$ 6.3) (Jia, Shen, & Xu, 2001; Zhang, Ping, Zhang, & Shen, 2003). Another major problem is its poor durability on cotton textile due to lack of strong bonding forces between the two polysaccharides (Lim & Hudson, 2004).

It was hypothesized that if a water soluble chitosan derivative could be developed it can lead to development of a multifunctional finish. Cotton can be made antimicrobial, its dyeability can be modified or enhanced and treatment with chitosan can also impart wrinkle recovery property to it. Water soluble carboxymethyl chitosan (CMCH) was prepared. This paper reports the process for development of a chitosan based finish on cotton. Besides the antimicrobial activity on cotton fabric, other textile properties such as dyeability, durability and performance characteristics have also been studied.

2. Experimental

2.1. Materials

Four chitosan samples (CH1, CH2, CH3 and CH4) having varying molecular weight and DD were used in the study. Three of these were commercial samples provided

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Table 1
Characteristics of chitosan samples used in screening study

Chitosan sample	DD (%)	Mol. wt. (kDa)
CH-1	73.42	41.25
CH-2	77.61	15.00
CH-3	93.12	28.89
CH-4	87.57	66.00

DD, degree of deacetylation; Mol. wt., molecular weight.

Table 2
Type and specification of different kinds of dyes

Name of dye	Class of dye	λ_{max} (nm)	Designation
Direct scarlet	Direct	500	Direct dye-1
Sky blue FFS	Direct	635	Direct dye-2
Polar brilliant red 10B	Acid	583	Acid dye-1
Polar yellow 5G	Acid	430	Acid dye-2
Remazol yellow	Reactive	400	Reactive dye-1
Procion yellow HE	Reactive	407	Reactive dye-2
Methylene blue 2B	Basic	665	Basic dye-1
Malachite green XLS	Basic	615	Basic dye-2

by India Sea Foods, Kochi (India) and the fourth (CH4) was a pure sample purchased from Aldrich Chemicals Ltd. All samples were characterized for degree of deacetylation (DD) by FTIR and molecular weight (Mol. Wt.) by intrinsic viscosity experiment using Ubbelhode viscometer. Their specifications are given in Table 1.

Two strains of waterborne pathogens, *Escherichia coli* (*E. coli*) and *Staphylococcus aureus* (*S. aureus*) were obtained from the American Type Culture Collection (ATCC). Fresh inoculants for antibacterial assessment were prepared on nutrient agar at 37 °C for 48 h. All tests on specimens in liquid culture were conducted in nutrient broth.

Bleached cotton fabric (110 gsm, 98 epi and 84 ppi.) was used as test fabric. The cotton fabric was further scoured using 5gpl Lissapol D at 60 °C for 30 min at MLR of 1:30. Dyeing of untreated and treated samples was carried out using different dyes. The dyes used with their specifications are given below (Table 2).

2.2. Preparation, characterization and water solubility of carboxymethyl chitosan

2.2.1. Preparation and characterization of carboxymethyl chitosan

Out of the four test chitosan samples, the one showing the highest degree of deacetylation was selected for preparing carboxymethyl chitosan using the method reported in literature (Liu, Guan, Yang, Li, & Yao, 2001).

Chitosan (10 g), sodium hydroxide (13.5 g), and solvent (100 ml) were added into a flask (500 ml) to swell and alkalize at room temperature (25 °C ± 2 °C) for 1 h in a water bath (Julabo Water bath Temperature Controlled). Monochloroacetic acid (15 g) dissolved in 20 ml isopropanol was added to the reaction mixture drop-wise for 30 min and reacted for 4 h at the same temperature. Reaction was stopped by adding 70% ethyl alcohol (200 ml). The solid was filtered and rinsed in 90% ethyl alcohol to desalt and dewater, and vacuum dried at room temperature. The carboxymethyl chitosan was produced by suspension of the solid in 100 ml of 80% ethyl alcohol followed by addition of 10 ml HCl (35–37%) per gm of solid for 30 min with stirring. The product was then filtered and rinsed in 70–80% ethyl alcohol and vacuum dried.

Characterization of carboxymethyl chitosan sample was performed by using Fourier Transform Infrared Spectroscopy. FTIR characterization of carboxymethyl chitosan samples was carried out in the form of potassium bromide pellets (KBr).

2.2.2. Solubility

The solubility of prepared carboxymethyl chitosan was tested in a broad range of pH (2–11). pH of solutions was maintained using 0.5% acetic acid and 0.5% sodium hydroxide.

2.3. Testing antimicrobial activity in solution

Two series of antimicrobial tests were performed on chitosan solutions. In the first case, comparison of antimicrobial activity of the four chitosan samples CH1, CH2 CH3 and CH4 was carried out by disk diffusion method on an agar plate. Diameter of the zone of inhibition was measured as per the standard test procedure ATCC 6538 according to SN 195 920.

To prepare an agar plate, solid culture was prepared by mixing 2 g agar–agar, 0.5 g peptone and 0.3 g beef extract in 100 ml distilled water. The agar plate was prepared by pouring the solid culture onto sterile circular plates and allowing it to solidify in the Stericlean Vertical Laminar Flow chamber. One hundred microliters of microbial culture was uniformly distributed on each plate. Five millimeter disks of filter paper were placed on the plates and impregnated with chitosan solutions of four different concentrations (0.1%, 0.2%, 0.5% and 0.75%) in 1% (w/v) acetic acid. The plates were placed in an incubator for 24 h at 37 °C. The zone of inhibition was then measured and recorded.

In the second set of experiments, the antimicrobial activity of unmodified chitosan CH3 was compared with that of its modified version CMCH in solution by studying the growth kinetics of *S. aureus* and *E. coli*. This was done by measuring the optical density of the microbial culture at 600 nm after 0–27 h of incubation. Optical density was measured using Perkin-Elmer Lambda 25 UV/vis Spectrophotometer.

2.4. Treatment of fabric with chitosan

Cotton fabric samples were padded with carboxymethyl chitosan and chitosan using a laboratory padder at 85% wet pick up. The padded fabrics were dried at 80 °C for 5 min

and cured at 150 °C for 3 min. The treated fabric samples were washed in distilled water, dried and placed in a dessicator till further study. Weight add-on was determined after conditioning the samples and comparing initial weight (before treatment) and final weight (after treatment).

2.5. Antimicrobial activity of treated cotton fabric samples

The antimicrobial activity of chitosan and carboxymethyl chitosan treated cotton fabrics was tested against Gram-negative bacteria *E. coli* and Gram-positive bacteria *S. aureus* by using colony counting method ASTM E 2149-01.

A liquid culture was prepared by mixing 0.5 g peptone and 0.3 g beef extract in 100 ml water. 1 in. × 1 in. size fabric sample was cut and put into 10 ml of liquid culture, to which 10 μl of microbe culture was inoculated. All samples were incubated for 24 h at 37 °C. From each incubated sample, 100 μl of solution was taken, diluted and distributed onto an agar plate. All plates were incubated for 24 h and the colonies formed were counted using Yorko colony counter. All inoculations and plating were done in Stericlean Vertical Laminar Flow Chamber. The percentage reduction was determined as follows:

$$\text{Reduction in cfu } (\%) = \frac{(C - A)}{C}$$

Where, C and A are the colonies counted from the plate of the control and treated samples, respectively.

2.6. Physical properties of treated cotton fabric samples

The treated cotton fabrics were characterized in terms of bending length, wrinkle recovery angle (WRA) in dry state and whiteness index (WI) to see if the treatment had any detrimental effect on the physical properties. The bending length was measured using a bending length tester (Paramount Stiffness Tester) based on the cantilever principle. The wrinkle recovery property of the fabrics was measured as per the standard method: AATCC Test Method 66-1975. The whiteness of treated fabrics was measured by CIE whiteness index using Gretag Macbeth Color eye −7000A.

2.7. Dyeability study on treated cotton fabric samples

2.7.1. Dyeing process

Depending on the class and particular kind of dye stuff used in the study, different dyeing recipes and dyeing cycles

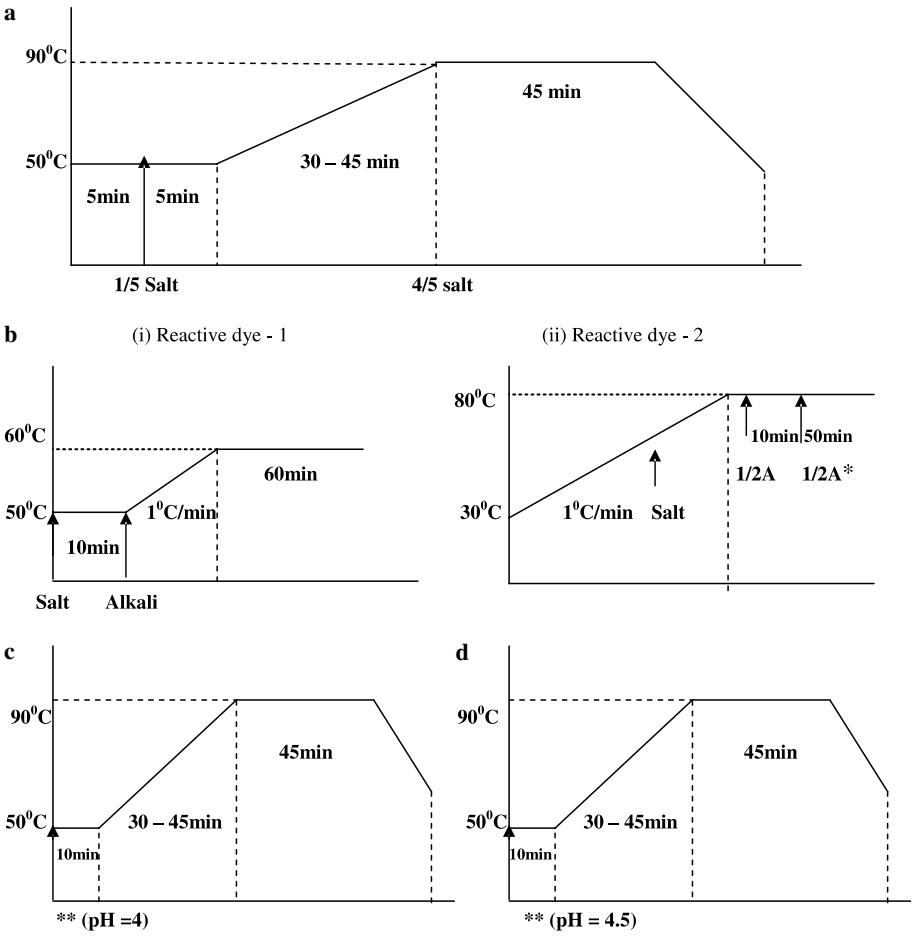

Fig. 1. Dyeing cycles for (a) direct dyes, (b) reactive dyes, (c) acid dyes and (d) basic dyes (*sodium carbonate alkali (A) is divided into two and added at 10 min interval at two points, **pH adjusted using acetic acid).

were used. All dyeing processes were carried out at 0.5% (owf) shade. Glaubers' salt (10 g/l) was used in direct dyeing for exhaustion. Glaubers' salt (50 g/l) and sodium carbonate (15 g/l) were used in reactive dyeing for exhaustion and fixation, respectively.

Dye bath pH (4–5) in acid and basic dyeing was adjusted by acetic acid. Dyeing cycles for the different dyes used in this study are presented below (Fig. 1). The dyeing process was carried out using exhaustion method (MLR: 1:40) in a laboratory water bath.

2.7.2. Evaluation of dye uptake

2.7.2.1. Dye exhaustion. The percentage dye exhaustion for each dye was determined by comparing concentration of dye in dye bath before and after dyeing. This was done with the help of a spectrophotometer and a calibration curve. The exhaustion is calculated using the following expression:

$$\text{Ex. } [\%] = \frac{C_0 - C}{C_0}$$

Where, Ex is the total exhaustion, C_0 and C are concentrations of dye bath before and after dyeing, respectively.

2.7.2.2. Colour measurement. Color measurement of dyed fabrics was done by recording the K/S value for dyed samples using Gretag Macbath Color eye −7000A using Color i control software based on D65 Illuminant and 10^0 observer. The fastness to washing of the dyed fabrics was studied by recording the K/S values of samples before and after five laundering cycles. Laundering was done using a standard method AATCC 124-1975 (under test No. IIA).

3. Results and discussion

Four samples of chitosan –CH1, CH2, CH3 and CH4, having varying mol. wt and DD were used for the screening study. The antimicrobial activity of the four samples was compared in solution using the agar plate zone of inhibition method. The results did not reveal any specific relationship between the molecular weight, DD and the antimicrobial activity of chitosan samples, Fig. 2. The chitosan sample, CH3 having the highest degree of deacetylation (DD ~ 93%) and moderate molecular weight (29 kDa) showed highest antimicrobial activity against *S. aureus* and *E. coli* for most concentrations studied and was chosen for further study. It is henceforth referred to as CH.

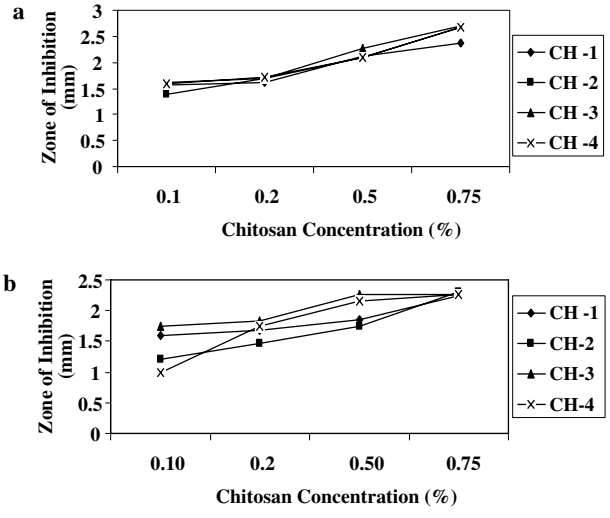

Fig. 2. Antimicrobial activity of different chitosan samples in solution against (a) *S. aureus* and (b) *E. coli*.

3.1. Preparation and characterization of carboxymethyl chitosan samples

CH was used to produce the carboxymethyl chitosan derivative CMCH. FTIR spectra, Fig. 3, of the same was recorded to determine the nature of substitution that had occurred.

The FTIR spectrum of CH (Fig. 3a) shows peaks assigned to the saccharide structure at 1149.7, 1072.6 and 897.9 cm^{-1}, and a strong amino characteristic peak at around 3400 cm^{-1}. Peaks at 1658 and 1325 cm^{-1}, are assigned to amide I and II bands, respectively. For CMCH (Fig. 3b) the characteristic peaks are observed at 1730 cm^{-1} (–COOH) which confirms that carboxymethylation has occurred. Furthermore, the peaks at 1074 cm^{-1} (–C–O–) and 1620 and 1520 cm^{-1} ($-NH^{3+}$) are characteristic peaks for *O*-carboxymethyl chitosan, indicating that substitution has occurred at the hydroxyl position of chitosan. This implies that the amino groups of chitosan which are responsible for antimicrobial activity are not involved in the substitution process, hence antimicrobial activity would not be affected (Liu et al., 2001).

3.2. Water solubility

After substitution, CMCH is expected to have better solubility characteristics. As shown in Table 3, CMCH is soluble in a wide range of pH in acidic and alkaline media while CH is completely soluble only below pH 6. It can be seen that CMCH is completely soluble at neutral as well as alkaline pH. The limited solubility of CH ($pK_a = 6.8$) is overcome by introduction of carboxy groups to the backbone of chitosan. Since all chemical processing of cotton is carried out at neutral or alkaline pH, this is desirable. The insolubility of CMCH around pH 4–5 could be due to the temperature and solvent mix used in its preparation (Chen & Park, 2003).

3.3. Antimicrobial activity of CMCH and CH

3.3.1. Effect of substitution and concentration on growth of microbes

To see the effect of CH substitution on antimicrobial activity, the growth kinetics of *S. aureus* and *E. coli* were

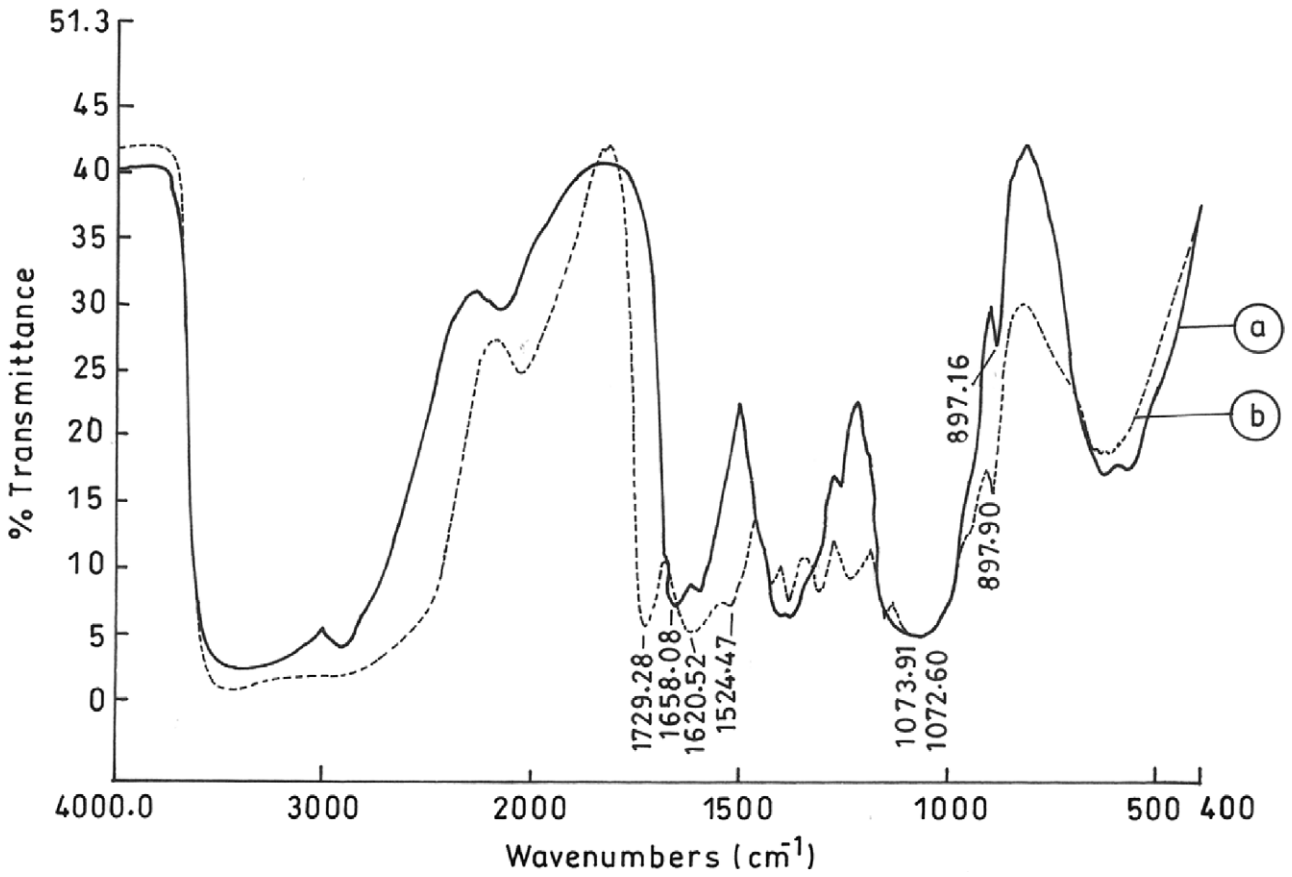

Fig. 3. FTIR spectra of chitosan (a) and carboxymethyl chitosan (b).

Table 3
Solubility of CH and CMCH at different pH

pH	2	3	4	5	6	7	8	9	10	11
CH	S	S	S	SS	SS	I	I	I	I	I
CMCH	S	S	I	SS	S	S	S	S	S	S

CH, chitosan; CMCH, carboxymethyl chitosan; S, soluble; SS, slightly soluble; and I, insoluble.

studied in the presence of modified and unmodified chitosan. In some earlier studies (Liu et al., 2001) it has been shown that carboxymethylation could result in lower antimicrobial activity. This happens when the substitution occurs at the amino position. In Fig. 4 it can be seen that in both cases microbial growth is significantly inhibited in the presence of chitosan. As shown in FTIR spectra, the substitution has occurred only at hydroxyl position, thus CMCH shows antimicrobial activity similar to that of CH.

Having ensured that there is no reduction in antimicrobial activity on substitution, the effect of concentration of CMCH on antimicrobial activity was studied spectrophotometrically against *S. aureus*. The results are shown in Fig. 5. Here also the behaviour of the two samples was found to be quite similar. In each case there was significant inhibition of microbes even at the minimum concentration (0.1%) used. No significant

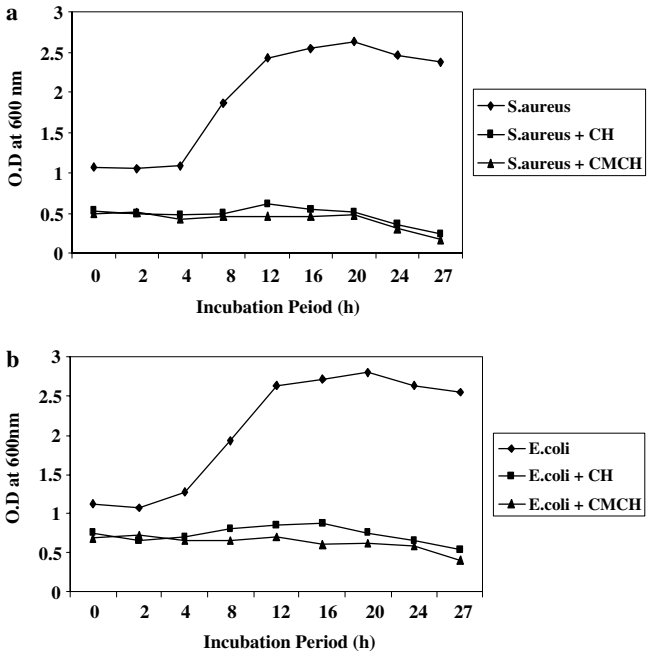

Fig. 4. Growth kinetics of (a) *S. aureus* and (b) *E. coli* in the presence of CMCH/CH.

increase in antimicrobial activity was observed beyond 0.5% which appears to be the maximum concentration that should be used.

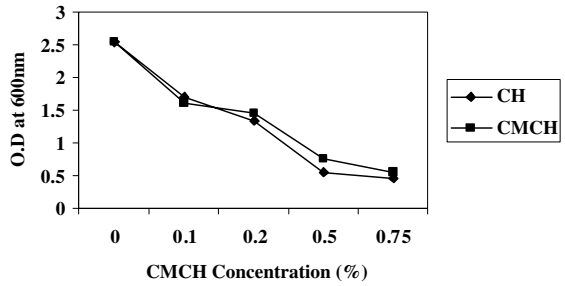

Fig. 5. Effect of concentration on antimicrobial activity of CMCH against *S. aureus*.

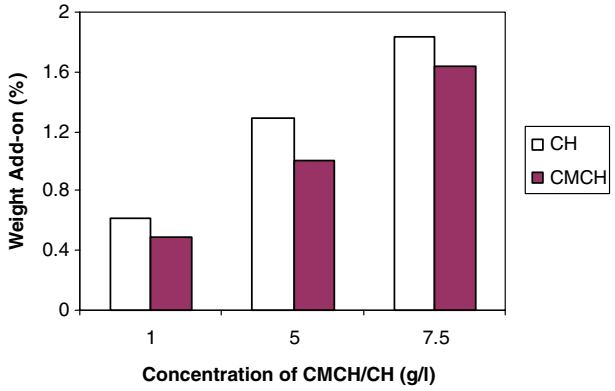

Fig. 6. Weight added on to cotton vs. CMCH/CH concentration.

3.3.2. Treatment of cotton fabric with CMCH and CH

Having studied the antimicrobial properties of CMCH/CH in solution form, the next step involved their application on cotton fabric. The weight add-on after treatment showed that there is a direct relationship between concentration of CMCH/CH and add-on percentage on cotton fabric (Fig. 6).

In comparison, the add-on obtained by CH application is slightly higher than on CMCH application. This could be related to the viscosity and solubility properties of CH and CMCH, respectively.

Chitosan has no inherent affinity for cellulose and is thus held on cotton only by the numerous hydrogen bonds and Vander Walls forces of attraction. However, there is a possibility of acid catalysed covalent bond formation between the hydroxyl groups of cellulose and the carboxylic groups of CMCH at the high temperature of curing (150 °C) thus giving better fixation in this case.

3.3.3. Antimicrobial activity of cotton fabric samples treated with CMCH and CH

The percentage reduction of microbes in relation to add-on as a result of CMCH/CH application on cotton fabric is shown in Fig. 7. The percentage reduction at 0.5–0.6% add-on is about 60% for CMCH as well as CH applied to cotton fabric. No significant difference is obtained with further increase in concentration. Therefore a concentration of 1gpl corresponding to 0.5–0.6% add-on could be considered as the optimum for application on cotton fabric for high antimicrobial activity.

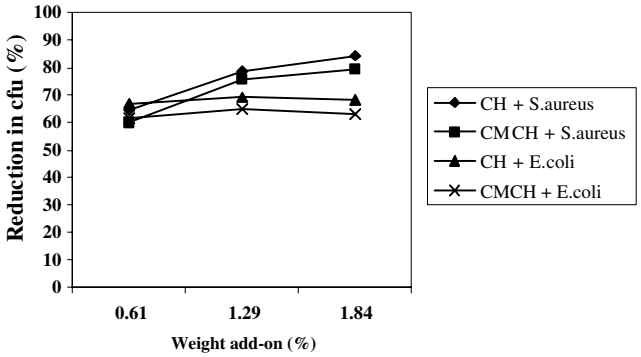

Fig. 7. Antimicrobial activity of CMCH/CH treated cotton fabrics.

In general, a higher reduction was observed for *S. aureus* as compared to *E. coli*, particularly at higher concentrations. It has also been shown that only low concentrations of antimicrobial agents are active against *E. coli* and the activity may actually go down at higher concentrations (Zitao, 2003).

3.4. Physical properties of CMCH and CH treated cotton fabric samples

Since chitosan is a high molecular weight polymer, its application to cotton can affect its feel and other physical properties. To ensure that the chitosan treatment had no undesirable effects, treated cotton was characterized in terms of several parameters related to its appearance and feel. The physical properties of fabric samples were compared by measuring the wrinkle recovery angle (WRA), Whiteness index (WI) and bending length.

All treated samples showed much higher wrinkle resistance as compared to control sample, Table 4. Wrinkle recovery angle was slightly lower for CMCH treated samples as compared to CH treated ones.

The difference in wrinkle recovery angle between CH and CMCH treated fabric samples could be due to the higher water solubility of CMCH. The solution in this case is much less viscous than that of CH. Thus, the film deposited on cotton in case of the former would be finer and more flexible than the latter. All treated fabrics show slightly lower whiteness.

Another physical property tested was bending length, which is a measure of stiffness of the treated fabric samples.

Table 4
Physical properties of CMCH/CH treated fabric samples

Fabric treatment	WRA	WI	BL (cm)	
			Warp	Weft
Control fabric	118	89.2	2.2	1.7
CH treated	172	80.6	2.9	2.4
CMCH treated	148	82.3	2.6	2.3

WRA, wrinkle recovery angle; WI, whiteness index; BL, bending length.

All treated samples showed slightly higher bending length/stiffness than the control sample indicating that the feel was not affected adversely by the treatment.

3.5. Dyeability of cotton fabric treated with CMCH and CH

It is generally difficult to dye cotton in deep and bright shades at low cost. Since cotton fabric has been significantly functionalized by the application of modified chitosan, it is expected that its dyeing behaviour would also be modified. Hence, anionic and cationic dyes were applied to treated cotton to study the effect of treatment on the degree of dye exhaustion, color strength (K/S) obtained and the durability of dyes to laundering.

3.5.1. Dye exhaustion and color measurement

The percent exhaustion of dyes and K/S value of cotton samples dyed with four classes of dyes is recorded in Table 5. All anionic dyes used in the study (direct, reactive and acid) showed higher dye exhaustion on CMCH/CH treated cotton than untreated cotton sample. The colour strength of treated fabric samples was also higher. Among the treated samples, CH treated samples showed higher dyeability with anionic dyes. On the other hand, in dyeing with basic dyes which are cationic in nature, higher color yield was obtained on samples treated with CMCH.

This could be explained based on the forces of repulsion and attraction expected to occur during the dyeing process. These forces arise due to the presence of free hydroxyl groups in cotton cellulose, anionic and cationic groups present in dyes, amino [NH^{3+}] and carboxylic [COO–] ions in carboxymethyl chitosan and amino [NH^{3+}] ions in chitosan, besides other factors.

In dyeing with the anionic dyes, the presence of amino groups on CH and CMCH treated cotton reduces the repulsion between the free hydroxyl groups of cellulose and the anionic groups of dyes. As a result, treated fabric samples showed higher color strength after dyeing with these dyes. The lower color yield on CMCH treated samples can be attributed to the presence of COO– groups which repel the dye anions thus giving a lower colour yield.

In dyeing with cationic dyes, however, the presence of amino groups on CH results in repulsion of cationic groups in these dyes and hence the color yield is lowered. On the other hand the presence of COO– on CMCH fabric samples enhances the ionic interaction with dye cationic groups hence improving the color yield of dyed fabric samples.

Overall, while there is a reduction in dyeability of CH treated cotton with basic dyes, treatment with CMCH has resulted in better dyeability of cotton with both anionic and cationic dyes.

3.5.2. Washing fastness of dyed fabric samples

The dyeing studies showed that the color yield on cotton improved for most samples treated with CH and CMCH. The additional dye taken up is most likely attached to the CMCH/CH and not to cellulose. Thus the wash fastness of the dye would depend on the bonding between dye and CMCH/CH as well as the bonding between CMCH/CH and cellulose. To study this effect, the washing fastness of the dyed fabrics was evaluated.

In can be seen from Table 5 that the K/S values of dyed CH and CMCH treated fabric samples showed lower reduction after repeated washing (5 wash cycles) compared with untreated ones. The ionic interactions between anionic dyes and the amino ions in CH and CMCH and cationic dyes and carboxy ions in CMCH treated samples improve the wash fastness of dyes on cotton. But the maintenance of colour strength by CH treated fabric with basic dyes was shown to be lower than untreated ones because of reasons cited earlier.

3.6. Antimicrobial properties of dyed fabrics

The antimicrobial property of CH/CMCH treated cotton fabric samples dyed with the different dyes was studied. Comparison among the dyed samples was made by the quantitative method of counting microbial colony forming units (cfu) of *S. aureus*. Results are reported in Table 6.

The antimicrobial activity of treated cotton samples decreases to a large extent after dyeing with anionic dyes (direct, reactive and acid) as shown by lower reduction in

Table 5
Exhaustion and colour strength of dyed cotton fabric

Type of dye	Exhaustion of dyes (%)			K/S value of dyed samples before and after washing		
	Untreated	CH treated	CMCH treated	Untreated	CH treated	CMCH treated
Direct dye-1	87.8	90.4	88.3	4.11 (2.56)	4.7 (4.36)	4.14 (3.35)
Direct dye-2	84.5	86.5	85.3	2.39	2.87	2.5
Reactive dye-1	44.4	56.2	49.9	1.07 (0.55)	1.23 (1.08)	1.1 (0.89)
Reactive dye-2	87.5	93.6	88.4	0.61	0.79	0.62
Acid dye-1	52.5	97.4	54	0.37 (0.14)	1.1 (0.87)	0.73 (0.51)
Acid dye-2	28.4	90.1	62.3	0.18	0.33	0.24
Basic dye-1	59.1	43.8	62.5	1.44 (0.42)	1.27 (0.22)	1.7 (1.22)
Basic dye-2	51.2	45	57.3	1.22	1.13	1.59

Note: The values given in bracket are for dyed samples after five laundering cycles.

Table 6
Antimicrobial property of cotton fabric samples dyed with different dyes

Fabric treatment	Undyed	Dyed with direct dye-1	Dyed with reactive dye-1	Dyed with acid dye-1	Dyed with basic dye-1
CH treated	78.74	45.6	60.33	41.31	77.2
CMCH treated	75.59	43.2	70.25	51.18	73.2

cfu (Table 6). Dyeing with these dyes leads to almost 20% reduction in activity against *S. aureus* as compared to undyed samples.

The lowering of antimicrobial property of the anionic dyed samples is due to the capping of the positively charged amino groups by the dye anionic groups. The antimicrobial activity of chitosan is directly related to the number of free amino groups present on it. As some of these groups interact with the dye anions, the antimicrobial activity is lowered when treated cotton is dyed with anionic dyes. This is also evident from the fact that the wash fastness of treated samples is improved. In general it can be seen that with higher dye exhaustion, the antimicrobial activity is lowered as more and more of the amino ions are occupied by dye anions.

Unlike the anionic dyed fabrics, basic dyed samples retain antimicrobial activity. There is practically no difference in antimicrobial activity of the undyed and dyed samples (Table 6). Hence it may be concluded that treatment with CMCH renders cotton cationic dyeable. Treated samples show better colour yield, better fastness to washing as well as durable antimicrobial activity.

4. Conclusion

A water soluble chitosan derivative (CMCH) was prepared by carboxymethylation. It was applied to cotton with pad-dry-cure and the fabric was tested for dyeability, antimicrobial activity and durability to multiple launderings. Using a 0.1% solution of CMCH, a semi durable antimicrobial finish could be given to cotton which is active against Gram-positive bacteria *S. aureus* and Gram-negative bacteria *E. coli*. The treatment also made cotton basic dyeable. Dye exhaustion as well as the wash fastness of dyes improved after the treatment. Treated samples also had better dry wrinkle recovery as compared to untreated ones. The proposed treatment can thus be used to impart an eco friendly, multifunctional finish on cotton textiles.

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