Journal of Metals, Materials and Minerals, Vol. 29, No. 3, pp. 17-24, 2019

Antibacterial and physical properties of silver chloride-coated partially carboxymethylated cotton gauze

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Received date:
7 August 2018
Revised date:
29 May 2019
Accepted date:
30 June 2019

Keywords:
Carboxymethylation
Antibacterial
Silver
Cotton gauze

Abstract

Cotton gauze was modified by carboxymethylation to three different degrees of substitution (DS), and then coated with silver chloride (AgCl) and exposed to three different intensities of ultraviolet (UV) irradiation. The antibacterial activity and physical properties, such as the bursting strength, saline absorption and whiteness, of the different materials were then examined. In term of the antibacterial activity, the AgCl-coated unmodified cotton and carboxymethylated cotton (CM)-gauzes all showed good antibacterial activity against *Staphylococcus aureus* and *Escherichia coli*. With respect to the physical properties, the CM-gauzes with different DS values all showed a higher bursting strength and better saline absorption than those of the unmodified cotton gauze, but the unmodified cotton gauze had the highest whiteness index compared with that of the different CM-gauzes and their corresponding AgCl-coated CM-gauzes.

1. Introduction

Cotton gauze is a good material for incorporation into wound dressings due to its large porosity, good absorption ability, and good moisture and air permeability. Therefore, it is standard practice to use cotton gauze as a first aid material to cover wounds, relieve the bleeding on wounds and to pad wounds before they are bandaged. Wounds can heal more quickly if they are not infected with any foreign agents and are not fully covered with fluid that has wept out of a tissue as the result of injury, inflammation or inflection. A basic wound dressing should have the ability then to prevent these two factors from occurring on the wounds. At a minimum, antimicrobial and absorption abilities should be present in wound dressings. Normally, cotton gauzes have good absorption abilities but a poor ability to protect the wound from bacterial contamination and infection. Therefore, improving the antibacterial property of cotton gauzes, such as by coating or finishing with an antimicrobial finish, would remedy the drawback of using cotton gauze and so make it a more effective wound dressing material.

Antimicrobial finishes can be divided into two groups. The first is comprised of organic antimicrobial finishes, such as polyhexamethylene biquanide, ammonium chloride or chitosan, whilst the second is comprised of the inorganic antimicrobial finishes, such as titania, zinc oxide or silver nanoparticles (AgNPs). In this study, we chose to use silver chloride (AgCl) particles as an antimicrobial agent for coating on the cotton gauze, since silver salts have long been known to have antimicrobial properties, being successfully used as an antibacterial agent for centuries, and have also been used intensively in treating burn wounds. The antimicrobial or hygienic finish based on silver salts or AgNPs prevents the uninhibited multiplication of bacteria on the textile surfaces, whilst the natural balance of the skin is not affected [1-3].

Silver nitrate ($AgNO_3$) is normally used as the starting agent for the synthesis of the antimicrobial silver (salt or metal) nanoparticles and is the most popular silver salt solution used in burn wound therapy, but at a concentration of less than 0.5% (w/v). Moreover, ionic silver (Ag^+) solutions are highly bactericidal and have a beneficial effect in decreasing the wound surface inflammation, where $AgNO_3$ has been used as an antiseptic agent in hospitals for a long time at up to 0.5% (w/v), a concentration that provides an effective antimicrobial activity without damaging the human tissue [4]. In contrast, $AgNO_3$ concentrations exceeding 1% (w/w) are toxic to the tissue due to nitrate toxicity, and so the resulting decreased healing rate offsets to some degree the beneficial antibacterial effect of the Ag^+ ions [5].

$AgNO_3$ solutions are unstable when exposed to light and will produce black stains on the substrate. Since Ag^+ ions adhere to the cotton fiber via electrostatic interactions, then cotton fibers without any surface modification absorb very low levels of Ag^+ ions. To improve the absorption of Ag^+ ions onto the cotton fibers, the cotton fibers need to be chemically modified to increase the surface density of net negatively charged groups. For example, the absorption of Ag^+ ions on cotton fibers was enhanced by grafting with glycidyl methacrylate-iminodiacetic acid [6]. Carboxymethylation is another simple method

DOI: 10.14456/jmmm.2019.29

to modify cotton to increase the negative charge density, and has been performed with sodium hydroxide and monochloroacetic acid by the exhaustion method, resulting in an increased absorption ability and Ag^+ ion binding ability of the cotton gauze. At a degree of substitution (DS) of 0.2 or less, carboxymethylation of the cotton alters several properties from that of that untreated cotton and resulted in several advantageous properties, including an increased wettability, moisture retention and water solubility, changed dyeing characteristics, improved ease of soil removal and an increased reactivity to further chemical treatment allowing the production of an antimicrobial cloth [7-9].

The objective of this research was to modify the cotton gauze by carboxymethylation using the exhaustion method to obtain partially carboxymethylated cotton gauze (CM-gauze) with three different DS levels. After that, the CM-gauzes with different DS values were coated with AgCl and then exposed to ultraviolet (UV) irradiation at three different intensities. The effect of the DS of the CM-gauze on the ability to absorb Ag^+ ions was investigated, whilst the ability of different UV irradiation intensities to convert Ag^+ ions to metallic silver (Ag°) was evaluated using X-ray diffraction (XRD) analysis. In addition, the physical properties, including the saline absorption, bursting strength and whiteness, of the CM-gauzes were evaluated along with their respective AgCl-coated ones, with or without UV-irradiation at the three intensities, in comparison with the unmodified cotton gauze.

2. Experimental Method

2.1 Materials

Mill scoured and bleached loose plain weave cotton gauze, with a warp and weft density of 21 and 19 yarns/cm, respectively, was supplied by Limmer Co. Ltd., Thailand. Sodium hydroxide, hydrochloric acid, acetic acid, isopropanol and monochloroacetic acid were purchased from TC Sathaporn Group, Thailand. Ethanol and $AgNO_3$ were purchased from Labsystem Co. Ltd., Thailand. All chemicals used in this study were of analytical reagent grade.

2.2 Partially CM-cotton gauze formation by the exhaustion method

A ~20 g sample of cotton gauze was accurately weighed and placed into a 1000-mL beaker to which 400 mL of 80% (v/v) isopropanol in water was added and stirred for 30 min at ambient temperature. To this, 100 mL of 35% (w/v) sodium hydroxide was added drop-wise and stirred for another 30 min at ambient temperature. The carboxymethylation reaction was started by the addition of 100 mL of 15% (w/v) monochloroacetic acid dissolved in isopropanol and heating the mixture up to 70°C with constant mixing for 4 h (the reaction time). The treated cotton gauze was then taken out, washed by soaking in water, and neutralized by the addition of 0.5 M hydrochloric acid until the pH reached 7. The treated cotton gauze was then removed, washed again with an excess of 90% (v/v) ethanol in water, and dried at 70°C for 1 h. The DS of the obtained dry CM-gauze was evaluated and it was then coated with AgCl where applicable as below. This procedure was repeated as above except changing the monochloroacetic acid concentration to 20% and 25% (w/v), to give a CM-gauze with a higher DS.

2.3 Coating of the cotton gauze and CM-gauze with different DS values with AgCl

The cotton gauze or CM-gauzes with different DS values, each at ~ 2.2 g, were individually immersed in 300 mL of 0.02 M $AgNO_3$ aqueous solution for 5 min at room temperature, and then passed through a padder to obtain a wet pick-up level of 80-90%. Each respective padded gauze was then dried at 60°C for 5 min, re-immersed in 300 mL of 0.02 M sodium chloride (NaCl) aqueous solution for 5 min at room temperature, and padded as above. Finally, each respective padded gauze was dried at 60°C for 5 min and then exposed to UV irradiation at one of three different intensities of 300 (UV1), 500 (UV2) and 700 (UV3) mJ/cm^2 for one cycle.

2.4 Determination of the cotton DS with carboxymethyl groups

The determination of the DS was performed by a modification to the method of Miyamoto et al. [10] The DS of the carboxyl group on each CM-gauze was determined by attenuated total reflectance Fourier transformed infrared spectroscopy (ATR-FTIR) using Thermo Scientific Nicolet 6700 FTIR, where the DS was estimated from the IR spectra as shown in Eq. (1);

$$DS = R - 1 \quad (1)$$

Where as: R is the ratio of the absorption spectra of A_{1605}/A_{2880}.

The original cellulose sample had a DS value equal to zero. The ATR-FTIR absorptions at 1605 and 2880 cm^{-1} were assigned to the stretching vibration of the carboxyl (COO^-) and methane (C-H) groups, respectively. The ratio of these two absorption spectra (A_{1605}/A_{2880}) then gave the estimated relative amount of carboxyl groups in the tested sample.

2.5 Determination of the crystallinity and the morphology of Ag^+ ions formed on the AgCl-coated cotton gauze and AgCl-coated CM-gauzes

Samples were examined by XRD (D8 Advance Bruker AXS) with Cu Kα radiation at λ=1.5406 Å and a diffraction angle (2θ) between 5° and 90° for determination of the crystallinity. For morphology

determination, samples were examined by scanning electron microscopy (SEM) on a Jeol model JSM-6400 scanning electron microscope operated at 10 KV.

2.6 Determination of the absorption level of the gauzes in a 0.9% (w/v) NaCl solution

A 2 x 2 cm sample was prepared and weighed (W1), and then immersed in 100 mL of 0.9% (w/v) saline solution at 37°C for 30 min. The sample was then removed with forceps, drained for 30 sec and weighed to give the wet sample weight (W2). The fluid absorption in g/g was (W2-W1)/W1. The fluid absorption in g/100 cm^2 of gauze was calculated from (W2-W1) x 25 [4].

2.7 Antibacterial activity

The antibacterial efficacy of the cotton gauze was assessed according to the standard method of AATCC 100-1999-Antibacterial Finishes on Textile Materials. In this standard test, the percent bacterial reduction (R) was calculated from Eq. (2);

$$R = \frac{(A-B) \times 100}{A} \qquad (2)$$

Where A and B are the number of bacteria (as colony forming units/mL) recovered from the inoculated tested specimen (by washing) immediately after inoculation and after incubation for 24 h, respectively. Gram-positive *Staphylococcus aureus* (ATCC 6538) and Gram-negative *Escherichia coli* (ATCC 4352) were used as the test microorganisms.

2.8 Physical properties

The physical properties of each of the different gauze samples were characterized in terms of their bursting strength and whiteness index. The bursting strength was measured using a Tester SANGYO Digital Bursting Strength Tester following the standard method of ASTM D 3786-08-Standard Test Method for Bursting Strength of Textile Fabrics-Diaphragm Bursting Strength Tester Method. The whiteness index was measured according to the standard method of ASTM E 313-05-Standard Practice for Calculating Yellowness and Whiteness Indices for Instrumentally Measured Color Coordinates, using a Macbeth Color-eye 7000 spectrophotometer.

3. Results and Discussion

3.1 Chemical structure of the original cotton gauze and the CM-gauzes with a different DS of carboxymethylation

Cotton gauze was carboxymethylated with a mixture of monochloroacetic acid at three different concentrations of 15%, 20% and 25% (w/v) and sodium hydroxide at a constant concentration of 35% (w/v) by the exhaustion method. Representative ATR-FTIR spectra of the original cotton gauze (Control gauze) and the three different CM-gauzes are shown in Figure 1. The appearance of a new absorption band at 1605 cm^{-1}, found only in the CM-gauze samples, was attributed to the COO^- group. The intensity of this absorbance peak at 1605 cm^{-1} increased with increasing levels of monochloroacetic acid in the synthesis, presumably since higher monochloroacetic acid concentrations converted more –OH groups in the original cotton gauze to $–COO^-$ groups in the CM-gauzes. The broad and sharp absorption band at 3300 and 2880 cm^{-1}, respectively, are due to the stretching vibration of the –OH and C–H groups, respectively, and these two absorption bands appeared in all the gauzes.

3.2 The DS and physical characteristics of the different CM-gauzes

The calculated DS values of the CM-gauzes obtained using monochloroacetic acid concentrations of 15%, 20% and 25% (w/v) were 0.128, 0.385 and 0.843, respectively. Carboxymethylation caused a noticeable shrinkage in the CM-gauzes with DS values of 0.128, 0.385 and 0.843 to 70%, 68% and 50%, respectively, of that of the control group. The overall physical characteristics of the CM-gauzes with a DS value of 0.128 and 0.385 were still similar to that of the cotton gauze and had a soft touch, but the CM-gauze with a DS of 0.843 showed changed surface characteristics, forming a gel-like structure in appearance when immersed in aqueous solutions and was stiff or hard-to-the-touch on handling when dry. Therefore, the three CM-gauzes with different DS values were tested for their antibacterial activities, bursting strength, saline absorption and whiteness.

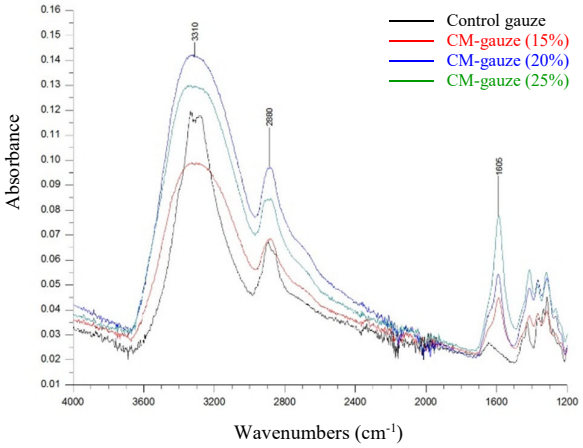

Figure 1. Representative ATR-FTIR spectrum of the cotton gauze (Control gauze) and CM-gauzes with different DS values of 0.128, 0.385, and 0.843, respectively.

3.3 XRD patterns of the different gauzes

Figure 2a shows the XRD patterns of the original cotton gauze and AgCl-coated cotton gauze without and with exposure to UV irradiation at the three different intensities (UV1-3). The original cotton gauze showed the three 2 theta peaks at 14.97°, 16.58° and 22.62°, which correspond to the diffraction peaks of the cellulose (JCPDS file no. 00-050-2241), as did the AgCl-coated cotton gauzes either without or with exposure to UV irradiation at the different intensities. No diffraction peak that corresponded to AgCl was evident on the AgCl-coated cotton gauze, which may reflect that the unmodified cotton gauze had insufficient functional groups to attach enough Ag^+ (as $AgNO_3$) for subsequent conversion to AgCl particles on the cotton gauze after treatment with $AgNO_3$ and NaCl solutions.

The CM-gauze with a DS of 0.128 showed an XRD peak at around 20° (Figure 2b), which was not the same peak as the diffraction peaks of cellulose. This may be because the carboxymethylation affected the crystallization form of the cellulose. After AgCl coating of the CM-gauze with a DS of 0.128, the three 2 theta peaks at 27.83°, 32.24° and 46.23° that corresponded to the diffraction peaks of the (111), (200) and (220) crystal planes of AgCl, respectively, were evident after UV irradiation at all three intensities (300-700 mJ/m^2) as well as in the samples without UV irradiation. However, after UV irradiation two further XRD peaks at a two theta of 54.83° and 57.48° that corresponded to the (311) and (222) crystal planes of AgCl were evident, indicating the face-centered-cubic nature of AgCl (JCPDS file no. 00-031-1238). These results are the similar to those results reported previously in other studies [12-13], but in addition, this result may imply that UV irradiation might affect the crystal formation of AgCl on the surface of the coated CM-gauze with a DS of 0.128.

The XRD patterns of the CM-gauze with a DS of 0.385 (Figure 2c) showed similar XRD peaks to those of the CM-gauze with a DS of 0.128 (Figure 2b). The XRD patterns of the AgCl-coated CM-gauze with a DS of 0.385 and those following UV irradiation at 300 and 500 mJ/m^2 showed diffraction peaks that corresponded to the diffraction peaks of AgCl particles (Figure 2c), and were similar to those obtained from the AgCl-coated CM-gauzes with a DS of 0.128 (Figure 2b). However, the diffraction peaks and the intensity of the peaks of the AgCl-coated CM-gauze with a DS of 0.385 and UV irradiated at 700 mJ/m^2 (UV3) were very different from the others, which might be because a high DS (0.385) and UV irradiation level (700 mJ/m^2) started to increase the amorphous structure and gelling feature on the surface of the modified cotton gauze. The XRD patterns of the AgCl-coated CM-gauze with a DS of 0.843 did not show any peak corresponding to the diffraction peaks of AgCl (Figure 2d), presumably because the amount of AgCl obtained from the $AgNO_3$/NaCl treatment was insufficient to be detected by XRD spectroscopy or it was not in a crystal form. The diffraction peaks corresponding to AgCl showed more clearly and at a higher intensity with increasing UV irradiation intensities, which is probably because the UV irradiation helped the growth of AgCl particles on the surface, but the net amount of AgCl was lower giving a lower peak intensity. It should be noted that the CM-gauze with a DS of 0.843 started to become stiff (when dry) and have a surface gelling characteristic when wet. These characteristics of the CM-gauze with a DS of 0.843 may attach AgCl particles in a different manner to that on the CM-gauzes with lower DS values. In this study, the three different intensities of UV irradiation were not able to change Ag^+ (AgCl) to metallic silver (Ag°), as confirmed by the XRD patterns where the diffraction peaks of the AgCl-coated CM-gauzes corresponded to those of AgCl but not Ag°. That the UV irradiation used in this study (300-700 mJ/m^2) could not convert Ag^+ to Ag° contrasts with that previously reported [14]. It remains to be evaluated if this is because the UV irradiation intensities used in this study were insufficient.

3.4 Morphology of the different gauzes (SEM analysis)

Representative SEM images of the different gauzes are shown in Figure 3. The surface of the origin cotton gauze and of the CM-gauzes with DS values of DS 0.128, 0.385 and 0.843 were clear and smooth without any particles deposited on the fiber surface. This implied that the carboxymethylation used to modify the cotton gauze did not significantly affect the surface appearance of the cotton gauze. The surface of the AgCl-coated cotton gauzes without exposure to UV irradiation had a few AgCl particles deposited randomly on the fiber surface, whilst the surfaces of the AgCl-coated CM-gauzes without exposure to UV irradiation at different DS values had more AgCl particles on the fiber surfaces than that of AgCl-coated cotton gauzes. The number of AgCl particles on the fiber surface of the AgCl-coated CM-gauzes (no UV irradiation) increased with higher DS values, reflecting their higher net negative charge density (from the carboxyl groups) to attach Ag^+ ions and then convert to AgCl particles in the silver (chloride) coating process. The surface of AgCl-coated cotton gauzes exposed to UV irradiation at either 300 or 500 mJ/cm^2 (UV1 or UV2) had a similar surface density of AgCl particles on the fiber surface, whereas after exposure to UV irradiation at 700 mJ/cm^2 (UV3) they had more agglomerates of AgCl particles. Presumably, at the higher UV irradiation intensity there was a higher influence on the growth of AgCl particles on the fiber surface.

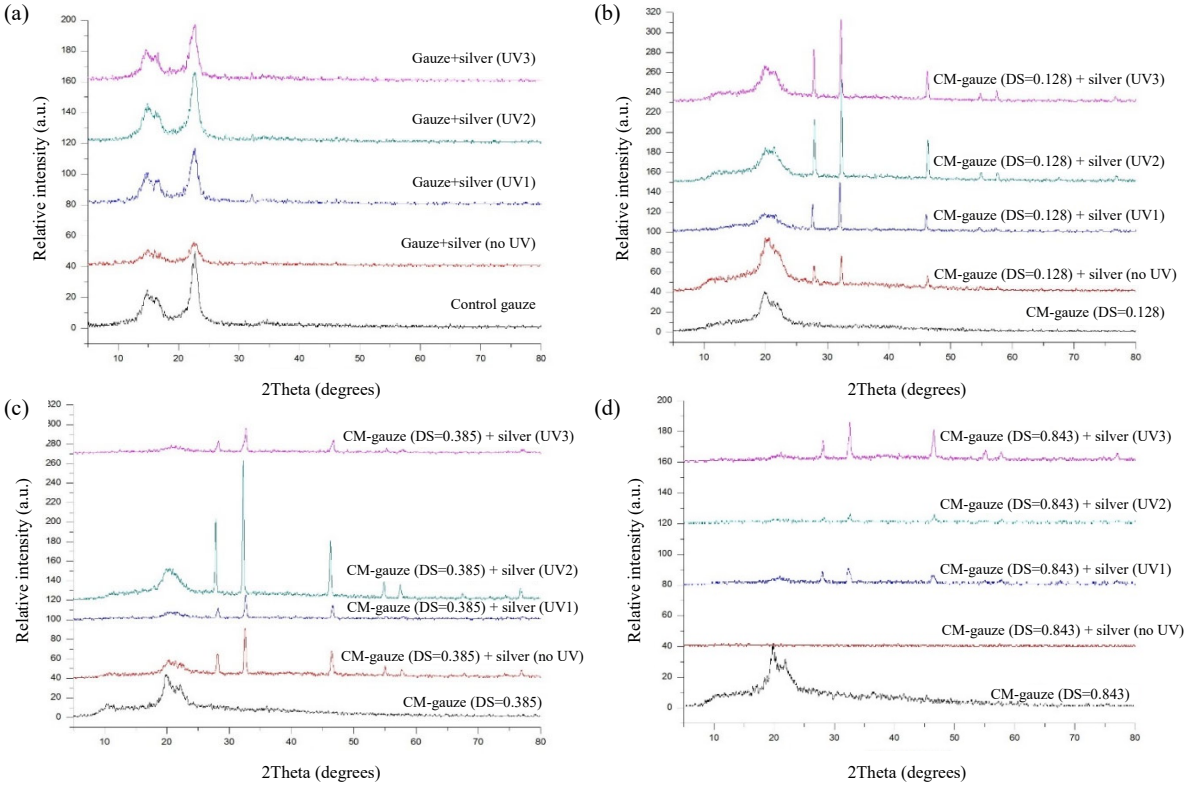

Figure 2. XRD patterns of the (a) original cotton gauze (Control gauze) and (b–d) the CM gauze with a DS of (b) 0.128, (c) 0.385 and (d) 0.843 plus in each case the respective AgCl-coated gauze without (no UV) or with exposure to UV irradiation at 300 (UV1), 500 (UV2) and 700 (UV3) mJ/cm^2.

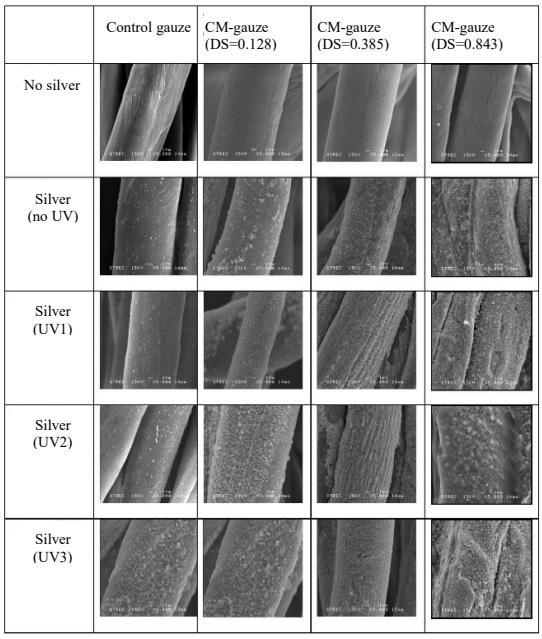

Figure 3. Representative SEM images (5000 x magnification) of the original cotton gauze (control gauze) and the CM-gauzes with different DS values without (no UV) or with exposure to UV irradiation at 300 (UV1), 500 (UV2) and 700 (UV3) mJ/cm^2.

The AgCl-coated CM-gauzes with a higher DS, after exposure to UV irradiation, had a higher amount of agglomerated AgCl particles on the fiber surface than those of the AgCl-coated cotton gauzes under UV irradiation. This result supported that the carboxymethylation of cotton gauze provided more negatively charged carboxyl groups on the gauze surface for attachment of Ag^+ ions to then be converted to AgCl particles in the coating process. The CM-gauze with the highest DS value (0.843) exposed to the highest UV irradiation level (700 mJ/cm^2) had the highest amount of AgCl particle agglomerates and also had cracks on the fiber surface. Thus, UV irradiation at 700 mJ/cm^2 started to damage the surface of the CM-gauze.

3.5 Absorption of saline solution by the different gauzes

The saline absorption levels of the different gauzes are summarized in Figure 4. Carboxymethylation of the cotton gauze resulted in shrinkage of the gauze by about 70%, 68% and 50% for the CM-gauzes with a DS of 0.128, 0.385 and 0.843, respectively, compared to the unmodified cotton gauze. This shrinkage provided a tight structure to the CM-gauzes that increased the saline absorption more than that of the original cotton gauze from 2.73-fold at a DS of 0.128 to 3.55-fold at a DS of 0.843. In addition, the CM-gauzes had a higher

net negative charge density (from the carboxyl groups), which enhanced the ability to attach sodium ions from the saline solution. The CM-gauze with the highest DS value (0.843) had the lowest shrinkage level, but provided the highest saline absorption level. This might be due to the gelling characteristic that occurred on the CM-gauze with a DS of 0.843, which could accordingly hold a much higher level of fluids than expected.

The AgCl-coated CM-gauzes without UV irradiation showed a slight decrease (1.07- to 1.16-fold) in the saline absorption level compared to the corresponding uncoated CM-gauzes of the same DS value, which was likely to be because some of the negatively charged carboxyl groups on the CM-gauzes had bound Ag^+ ions and so had a reduced negative charge density to attach sodium ions from the saline solution. UV irradiation at all three irradiation levels of the AgCl-coated cotton gauze and CM-gauzes with a DS of 0.128 or 0.385 had only a slight (1.13-fold) reduction or essentially no effect on the saline adsorption level, respectively. In contrast, UV irradiation of the silver-coated CM-gauze with a DS of 0.843 resulted in an dose-dependent enhanced saline adsorption (1.23- to 1.32-fold), being highest at the highest irradiation level (700 mJ/m^2). Presumably the enhanced intensity of UV irradiation increased the gelling characteristic on the surface of AgCl-coated CM-gauzes with a DS of 0.843, or it may have affected the amorphous and crystallinity components in the structure of the AgCl-coated CM-gauze. These two factors independently or together would cause the gauze to hold more fluid than those with a non-gelling or high crystallinity structure. Thus, carboxymethylation of cotton gauze and especially carboxymethylation with AgCl particle coating followed by UV irradiation resulted in a better saline absorption than that of the unmodified cotton gauze. Accordingly, these modified cotton gauzes might absorb more fluid exudates and toxic components from the wound and protect the wound from infection better than the unmodified cotton gauze.

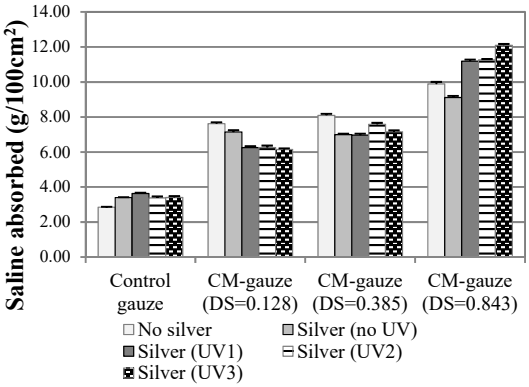

Figure 4. Saline absorption of the original cotton gauze (Control gauze) and the CM-gauzes with different DS values without (no UV) or with exposure to UV irradiation at 300 (UV1), 500 (UV2) and 700 (UV3) mJ/cm^2.

3.6 Whiteness

Carboxymethylation reduced the whiteness index of the cotton gauze slightly (1.01- to 1.1-fold) in a DS-dependent manner, where the higher the DS of the CM-gauze the lower the whiteness index was. However, coating the CM-gauze with AgCl without UV irradiation significantly (1.29-fold) reduced the whiteness index compared to the corresponding cotton gauze or CM-gauze without any AgCl covering (Figure 5a). This is likely to be because the $AgNO_3$ and AgCl were unstable when exposed to light and produced black stains that then affected the whiteness index. Exposure of the AgCl-coated gauzes to UV irradiation further reduced the whiteness index in a UV-dose dependent manner from 1.9- to 2.9-fold for the AgCl-coated cotton gauze and in a UV- and DS-dose dependent manner from 2.29- to 3.14-fold at 300 mJ/cm^2 to 3.4- to 11-fold at 700 mJ/cm^2, respectively, for the AgCl-coated CM-gauzes (Figure 5a).

3.7 Bursting strength

The bursting strength of the CM-gauzes was significantly greater (from 4.0-fold at a DS of 0.128 to 2.4-fold at a DS of 0.843) than the unmodified cotton gauze (Figure 5b). This may be due to the shrinkage of the gauze following carboxymethylation with a tighter construction of the CM-gauze compared to that of the original cotton gauze (Figure 5b). However, the CM-gauzes with a DS of 0.128 and 0.385 had a much higher (1.6-fold) bursting strength than that with a DS of 0.843, which is because the CM-gauze with DS of 0.843 started to become brittle when dry and form a surface gel when wet that decreased the bursting strength of the cotton gauze. Coating of the natural cotton gauze with AgCl without UV irradiation increased the bursting strength 1.26-fold, whilst subsequent UV irradiation increased the bursting strength by a further 1.5-fold at 300 mJ/cm^2 and 1.8-fold at 500 and 700 mJ/cm^2 (Figure 5b). However, AgCl coating had no significant effect on the bursting strength of the CM-gauzes and subsequent UV irradiation only increased the bursting strength of the CM-gauze with a DS of 0.893 when at the two higher irradiation doses of 500 and 700 mJ/m^2 (1.4- and 1.28-fold, respectively).

3.8 Antibacterial property

The cotton gauze and the CM-gauzes with a DS of 0.128, 0.385 and 0.843 did not show any detected antibacterial activity against the two tested model species. The AgCl-coated cotton gauze and the AgCl-coated CM-gauzes with or without subsequent UV irradiation showed a very high antibacterial activity, in terms of almost 100% reduction in the number of viable *S. aureus* and *E. coli* colonies (Table 1).

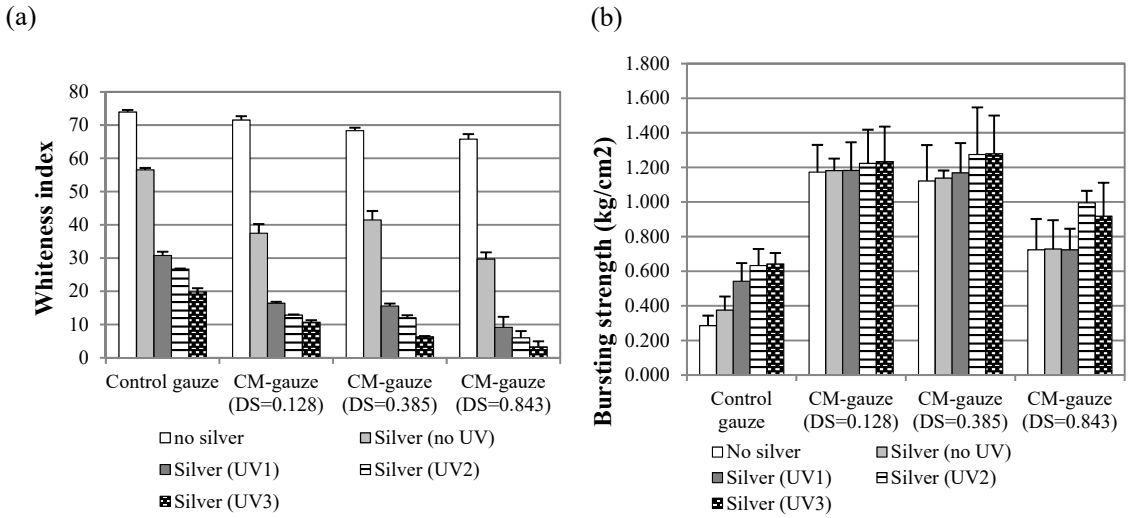

Figure 5. The (a) whiteness index and (b) bursting strength of the original cotton gauze (Control gauze) and the CM-gauzes with different DS values and their corresponding AgCl-coated counterparts without (no UV) or with UV radiation at 300 (UV1), 500 (UV2) and 700 (UV3) mJ/cm^2.

Table 1. Antibacterial properties of the control gauze, the CM-gauzes with different DS values and their corresponding AgCl-coated counterparts without (no UV) or with UV radiation at 300 (UV1), 500 (UV2) and 700 (UV3) mJ/cm^2.

Tested sample	**% Reduction of bacteria colonies**	
	Staphylococcus aureus	***Escherichia coli***
Control gauze	0	0
Gauze + silver (no UV)	90.30	89.65
Gauze + silver (UV1)	99.09	99.99
Gauze + silver (UV2)	99.54	99.99
Gauze + silver (UV3)	99.99	99.99
CM-gauze (15%) DS = 0.128	0	0
CM-gauze (15%) + silver (no UV)	99.99	99.99
CM-gauze (15%) + silver (UV1)	99.99	99.99
CM-gauze (15%) + silver (UV2)	99.99	99.99
CM-gauze (15%) + silver (UV3)	99.99	99.99
CM-gauze (20%) DS = 0.385	0	0
CM-gauze (20%) + silver (no UV)	93.93	99.99
CM-gauze (20%) + silver (UV1)	99.99	99.99
CM-gauze (20%) + silver (UV2)	99.99	99.99
CM-gauze (20%) + silver (UV3)	99.99	99.99
CM-gauze (25%) DS = 0.843	0	0
CM-gauze (25%) + silver (no UV)	99.99	99.99
CM-gauze (25%) + silver (UV1)	99.99	99.99
CM-gauze (25%) + silver (UV2)	99.99	99.99
CM-gauze (25%) + silver (UV3)	99.99	99.99

4. Conclusions

This research modified cotton gauze by carboxymethylation to different DS, and then these CM-gauzes were coated with AgCl and UV irradiated at three different intensities. The antibacterial activity and physical properties (bursting strength, saline absorption and whiteness) of all the obtained gauzes were evaluated. In terms of the antibacterial activity, the cotton gauze and CM-gauzes did not show any antibacterial activity against *S. aureus* and *E. coli*. In contrast, when the cotton gauze or the CM-gauzes were coated with AgCl they all showed a good antibacterial activity whether subsequently irradiated with UV light or not. The CM-gauzes with different DS values showed a higher bursting strength and saline absorption level than the unmodified cotton gauze, presumably due to the shrinkage of the cotton gauze during the carboxymethylation. However, the unmodified cotton gauze had the highest whiteness index compared with the CM-gauzes and, especially, the AgCl-coated CM-gauzes.

5. Acknowledgments

The authors thank the Chulalongkorn University graduate school thesis grant, Chulalongkorn University for financial support.

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