Available online www.jocpr.com

Journal of Chemical and Pharmaceutical Research, 2014, 6(11): 900-912

Research Article

ISSN : 0975-7384
CODEN(USA) : JCPRC5

Promising modification of cotton fabric for multifunctional applications

[1]Rehab M. Kotb*, [1]Naglaa A. A. Elsayed and [2]Abeer A. A. Salama

[1]Textile and Clothing Department, Faculty of Women for Arts, Science, and Education, Ain Shams University, Cairo, Egypt
[2]Pharmacological Department, National Research Centre, Cairo, Egypt

---

ABSTRACT

Present day numerous efforts have been done to the development of multipurpose textiles which fulfill the necessity requirements of consumer demands. In the present research woven cotton fabric surface was modified by adaptation of biopolymers such as chitosan and sodium alginate in addition to titanium dioxide, zinc oxide, and their mixtures to impart multifunctional properties. Cotton fabric surface was characterized by Scanning Electron Microscope (SEM) and Electron Dispersion Emission X-ray (EDX). Escherichia coli (E. coli) (Gram negative bacterium) and Staphylococcus aureus (S. aureus) (Gram positive bacterium) were used for estimation of antibacterial properties of coated samples and the maximum reduction% as well as excellent UV protection category (UPF 40-50+) were achieved with chitosan+ alginate+ metal oxides mixtures. In addition, fabrics wettability was enhanced significantly by different coating mixtures except for chitosan alone. Healing and anti-inflammatory properties showed remarkable enhancement for all coating mixtures and the strongest healing activity was found with chitosan+ alginate mixture in experimentally induced inflammation in rats. So, it could be claimed that the obtained coated fabrics were suitable for different applications such as medical applications as well as industrial products.

Keywords: Antibacterial, UV-blocking, anti-inflammatory, textiles, chitosan, alginate, metal oxides

---

INTRODUCTION

In recent years, the demand to modern textile materials has been increased due to the negative sides of human activity and civilization such as transport accidents, chemical materials, fire, cold, diseases, and sports [1]. So, the production of high value-added products such as, medical and protective textiles became one of the most important requirements for modern life [2]. These multifunctional properties can be merged with the traditional of textile products [1].

In addition to the harmful effects of ultraviolet radiation led to a considerable need for a photo-protection [3]. The most popular choices for protection from UV radiation are UV blocking textiles and sun blocking creams [4]. There are two types of UV blockers, the organic blockers or UV absorber since they absorb the UV rays and inorganic blockers which are usually certain semiconductor oxides such as TiO_2, ZnO, SiO_2, and Al_2O_3. Inorganic blockers are the preferred according to their exclusive features, non-toxicity, and chemical stability under both high temperature and UV -ray exposure [4]. Consequently, several studies have been carried out to block the textile fabrics against UV radiation [2,4,5].

Moreover, the antimicrobial products have been got a huge care as a result of infectious diseases outbreaks in the world [6]. The textile products are considered an appropriate media for microorganism's growth [7]. These microorganisms can reproduced quickly when the essential requirements, as moisture, nutrients and temperature are found. Proteins and carbohydrates in natural fibers can be nutrients and energy sources under certain conditions. As well as soil, dust, solutes from sweat and some textile finishes can also be nutrient sources for microorganisms [8]. The effects of microorganisms on textile itself caused many problems such as deterioration, staining and

discoloration in the fabric, furthermore likelihood of contamination and unpleasant odor of the wearer [8,9]. Thereby, many researchers aimed to utilize antimicrobial finishes to eliminate microbial attack for obtaining the aesthetic, hygienic or medical function [2,9,10,11]. Several antimicrobial agents have been used in the textile industry, chitosan, is the most non-toxic, biodegradable and biocompatible one [8]. Chitosan is a polycationic biopolymer, which has a wide spectrum of biological activity against bacteria, fungi; as well as it has haemostatic properties [12]. Additionally, it has been incorporated with alginate in order to obtain a highly absorbent bandage with antimicrobial properties [13]. Alginate has been used in wound dressing, as it is high absorbent material; therefore it is very appropriate for highly exuding wounds [10].

Alginate as well as chitosan is obtained from natural source, science both is biodegradable and having bio-adhesion, which make them more retention over the skin. The alginate as acidic linear polysaccharide composed of cell wall and intercellular cementing matrix algae can be converted into hydrophilic gel. This material provides a moist wound environment which promotes healing and epidermal regeneration. When using chitosan with alginate, they compose polyelectrolyte complexes (PEC) of oppositely charged polymers which have advantages when applied as coating materials and controlled release delivery carriers [13].

Subsequently, the current investigation was carried out in order to impart the cotton fabric multifunctional properties such as UV protection, antibacterial and wound healing by using chitosan, alginate, titanium dioxide and zinc oxide. The modified cotton fabrics can be used in different apparel applications such as medical and other different applications where there is a mast need for UV protection, antibacterial properties with wound healing.

EXPERIMENTAL SECTION

2.1. Fabric material

Half bleached, (2/2) plain weave 100% cotton fabrics (140g/m^2) was purchased from SHATEX, Egypt.

2.2. Chemicals

Chitosan (low molecular weight), sodium alginate, glacial acetic acid, citric acid, sodium hypophosphite, TiO_2, ZnO, peptone, beef extract, and agar, were of laboratory grade chemicals, a non ionic detergent Hostpal® CVL-EL, Miner binder SME2, and non ionic dispersing agent of commercial grade.

2.3. Microorganisms

Escherichia coli (*E. coli*) (Gram negative bacterium) and *Staphylococcus aureus* (*S. aureus*) (Gram positive bacterium), were used for estimation of antibacterial activities.

2.4. Media

Nutrient broth/ agar medium: contains beef extract (3 g/l), peptone (5 g/l). For solid medium (15 g/l) agar was added. This medium was sterilized for 20 min at 121°C under pressure.

2.5. Pharmacological studies

2.5.1. Animals

Wiser male rats, weighing ranged from 125-150g, were used throughout the experiment for the study of the anti-inflammatory activity. The rats were obtained from the animal house colony of the National research centre, Dokki, Giza, Egypt. The animals were housed in standard metal cages in an air conditioned room at 22 ± 3˚C, 55 ± 5% humidity and provided with standard laboratory diet and water *ad libitum*. Experiments were performed between 9:00 and 15:00 h. Animal procedures were performed in accordance with the Ethics Committee of the National Research Centre and followed the recommendations of the National Institutes of Health Guide for Care and Use of Laboratory Animals (Publication No. 85-23, revised 1985).

2.5.2. Drugs and Chemicals

Indomethacin cream (1%) was obtained from Ramida Pharmaceutical Industries Co, Egypt. Carrageenan was obtained from Sigma, USA.

2.6. Methods

2.6.1. The preparation of different mixtures

Different mixtures of the treatment solutions were prepared as follow:

- 2% (w/v) Sodium alginate solution.
- (2% w/v) chitosan was dissolved in 10% citric acid, sodium hypophosphite 10 g/l, and 0.5% glacial acetic acid.
- Mixture of chitosan and alginate solution of 1/1 ratio.
- 5% (w/v) Zn and Ti ions separately added to 1% (w/v) non ionic dispersing agent.

- Mixture of the previously prepared chitosan+alginate was mixed with the prepared solutions of ZnO and TiO_2 individually.
- Mixture of 18 g/l Miner binder added to the prepared ZnO and TiO_2 solutions.

2.6.2. The fabric treatment

The cotton fabric samples were impregnated in the prepared mixtures individually at 60 °C for 20 min. and were padded two (dips and nips) at a wet pickup (100 %). The treated samples were batched at room temperature for 2 hours then dried at (80 °C for 5 minutes) followed by curing at (140 °C for 3 minutes). Finally, the samples were washed with non-ionic detergent (2 g/L) at 40 °C for 20 minutes.

3. Testing and analysis

3.1. Scanning Electron Microscope (SEM) and Electron Dispersion Emission X-ray (EDX)

Scanning electron microscope (SEM) was used to obtain photomicrographs of fibers surface morphology by using JEOL-Model JSM-T20 operating at 30 kV. Electron Dispersion Emission X-ray (EDX) mode was applied for the elemental composition analysis. Gold layer was deposited on the samples before analysis.

3.2. Antibacterial properties

The antibacterial properties were quantitatively evaluated against gram negative bacteria, *Escherichia coli* and gram positive bacteria *Staphylococcus aureus,* according to AATCC test method 100- 1993. The reduction in numbers of bacteria was calculated using the following equation:

*Reduction rate (%) = (A-B)/A*100*

Where:
A = the numbers of bacterial colonies recovered from untreated fabrics and
B = the numbers of bacterial colonies recovered from treated fabrics.

3.3. Ultraviolet protection factor (UPF)

In vitro testing measures ultraviolet (UVR) transmission and the ultraviolet protection factor (UPF) was calculated according to the Australian/NewZeland Standard (AS/NZS-4399-1996) using UV-Shimadzu 3101-PC-Spectrophotometer. The following equation which based on the percent ultraviolet radiation transmittance through the specimen used to calculate the UPF.

Where:

$S\lambda$ = Solar spectral irradiance * ($W/cm^2/nm$)

* *(Is a function of the amount of solar energy that reaches the surface of the earth of each wavelength).*

$$UPF = \frac{\sum E\lambda \cdot S\lambda \cdot \Delta\lambda}{\sum E\lambda \cdot S\lambda \cdot T\lambda \cdot \Delta\lambda}$$

$E\lambda$ = Relative erythemal spectral effectiveness **

** *(Is a weighting spectrum of the action of UVR on the skin for each wavelength).*

$T\lambda$ = Spectral transmittance of the specimen (measured)

$\Delta\lambda$ = Measured wavelength interval or band width (nm.)

3.4. Fabric wettability properties

The wettability properties of untreated and coated fabrics were evaluated according to AATCC 79-2007 test method.

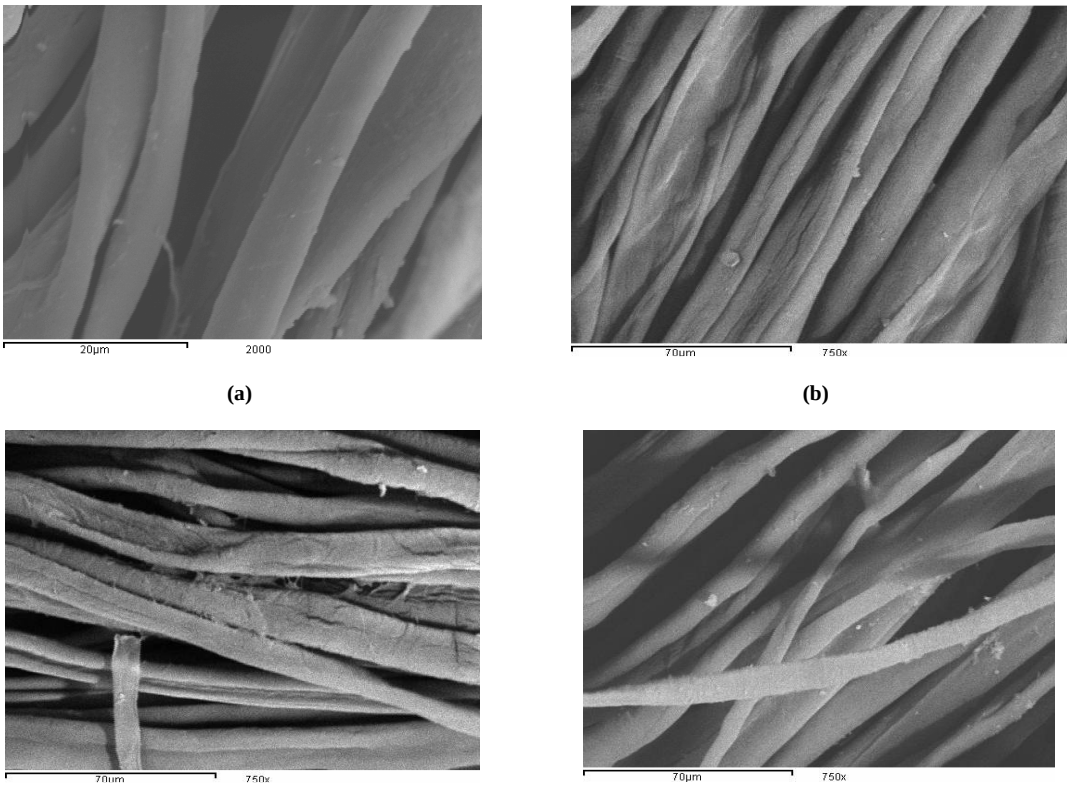
3.5. Carageenan-induced paw oedema for healing and anti-inflammatory properties evaluation

Paw swelling was elicited by sub-plantar injection of 100 µl of 1% sterile carrageenan suspension in saline into the right hind paw [14]. Contralateral paw received an equal volume of saline. The oedema component of inflammation was quantified by measuring hind footpad immediately before carrageenan injection and 1-4h after carrageenan injection with a micrometer caliber [15]. Oedema was expressed as a percentage of change from control (pre-drug) values. Rats were divided into fifteen groups each of six. Blank and treated clothes were applied around the hind paw immediately after the injection of the carrageenan suspension. We use indomethacin cream (1%) as a reference anti-inflammatory drug which applied to blank tissue.

RESULTS AND DISCUSSION

4.1. Characterization of treated cotton fabrics by SEM and EDX

The possible changes of the surface morphology after the treatment have been evaluated by scanning electron microscope (SEM). In addition to electron dispersion emission X-ray (EDX) mode was applied for the elemental composition analysis was shown in Figure (4). Comparing the SEM images; there are morphological changes clearly obvious between blank cotton fabric and the coated fabrics; shown in Figures (1a, 1b, 1c, 1d). These treatments created a type of a smooth film of chitosan, alginate, and chitosan+alginate mixture layers coated the fabric surface due to the polyelectrolyte complex (PEC) polymer of chitosan and alginate mixture.



(a) **(b)**

(c) **(d)**

Figure (1): SEM micrographs of chitosan, alginate, and their mixture coated fabrics

(a) Blank cotton fabric; (b) Chitosan coated fabric; (c) Alginate coated fabric; (d) Chitosan+alginate coated fabric

Figures (2a) and (3a) clearly showed that ZnO and TiO_2 particles are distributed on the fabric surface confirmed with EDX analysis; Figure (4a, 4b); are still present after washing producing Zn element concentration was 26.37 wt.% and Ti element concentration was 14.74 wt.% .In case of coating fabric with ZnO+binder mixture, TiO_2+binder mixture, pre-coated with chitosan+alginate post-loaded with ZnO, and pre-coated with chitosan+alginate post-loaded with TiO_2 shown in Figures (2b, 2d) and (3b, 3d), there are a larger bonding layers between fibers with presence of little agglomeration of metal oxides particles. Whereas, there are different SEM images obtained shown in Figures (2c) and (3c) in case of pre-loading cotton fabric with ZnO posted-coating with chitosan+alginate, and pre-loading cotton fabric with TiO_2 posted-coating with chitosan+alginate. This may be due to PEC polymer of chitosan+alginate may be created a type of second layer of coating that covered metal oxides particles, which confirmed with EDX images; Figure (4c, 4d); producing Zn element concentration was 0.65 wt.% and Ti element concentration was 10.7 wt.%.

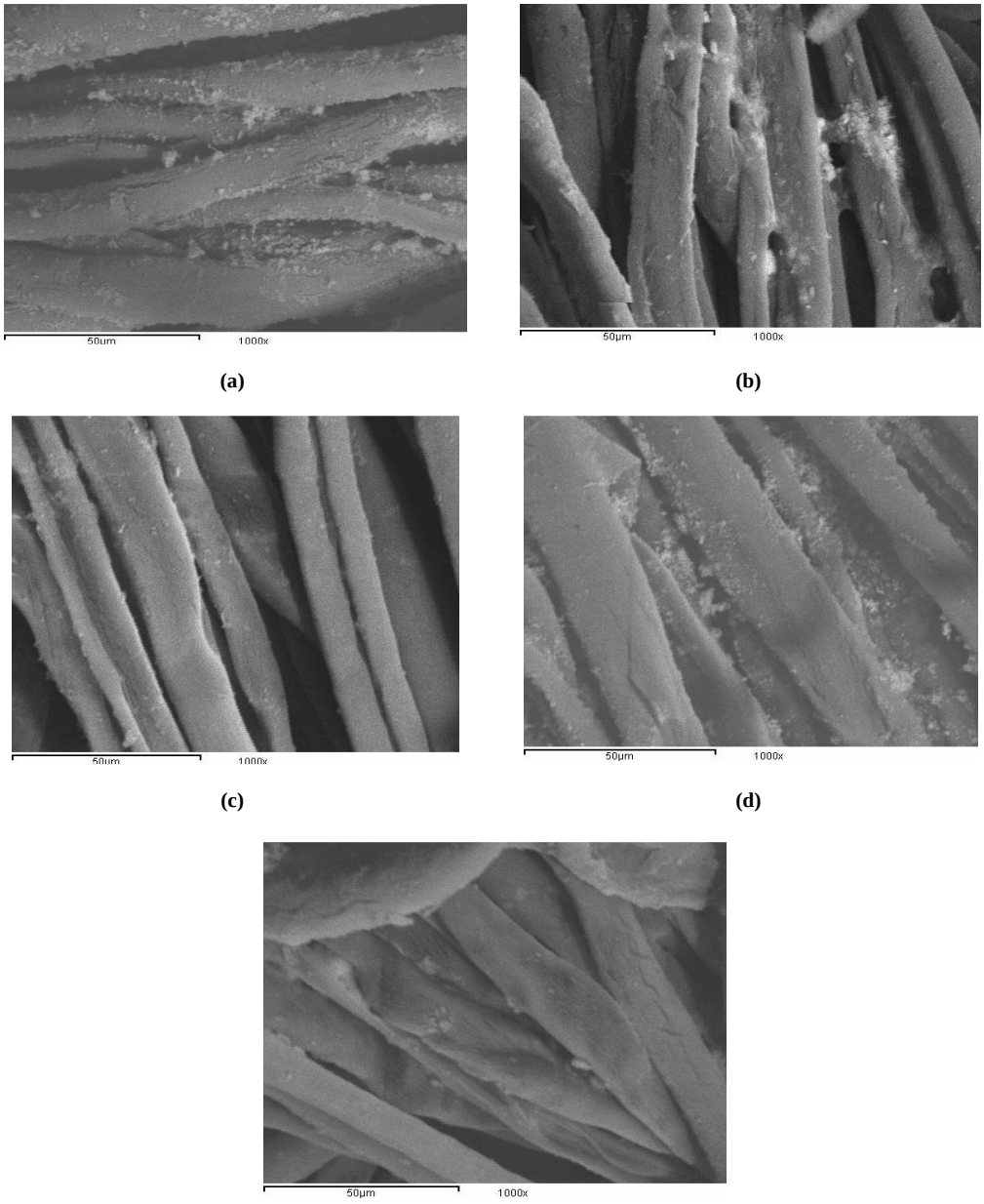
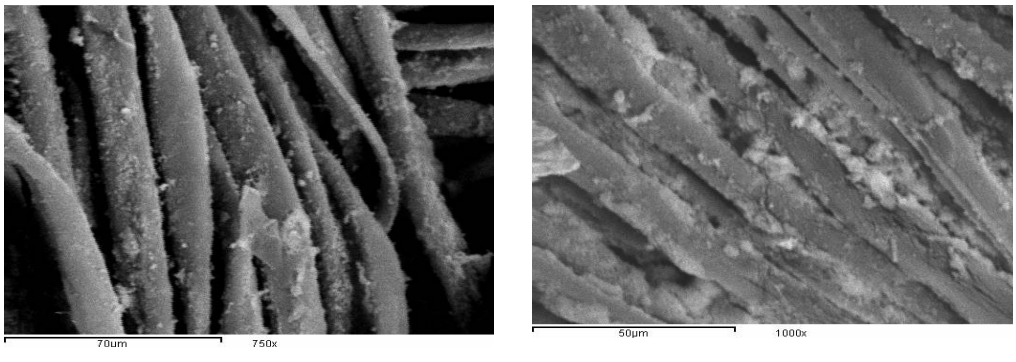
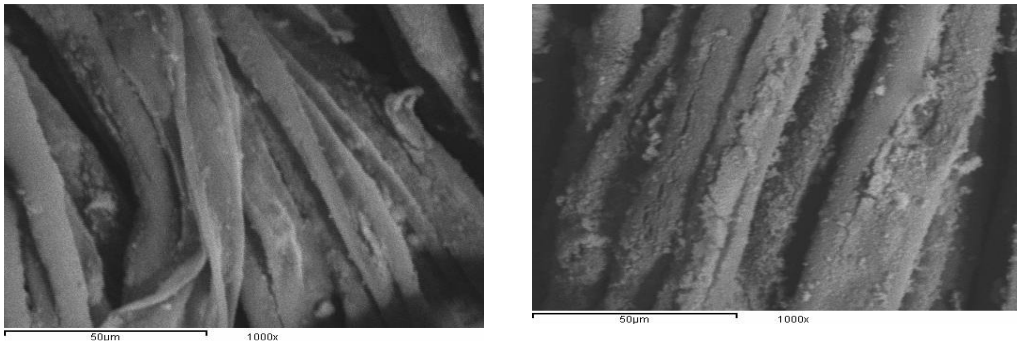
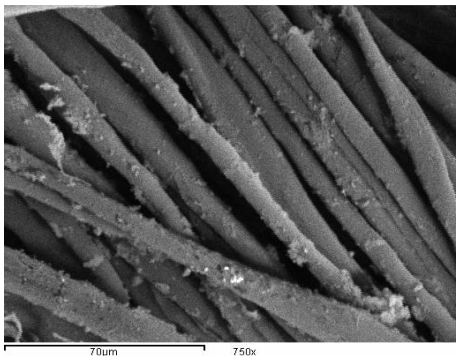


Figure (2): SEM micrographs of ZnO, ZnO+binder, Pre-loaded with ZnO posted-coated with chitosan+alginate, Pre-coated with chitosan+alginate post-loaded with ZnO, chitosan+alginate+ZnO coated fabrics (a) ZnO loaded fabric; (b) ZnO+binder coated fabric; (c) Pre-loaded with ZnO posted-coated with chitosan+alginate fabric; (d) Pre-coated with chitosan+alginate post-loaded with ZnO fabric; (e) chitosan+alginate+ZnO mixture coated fabric



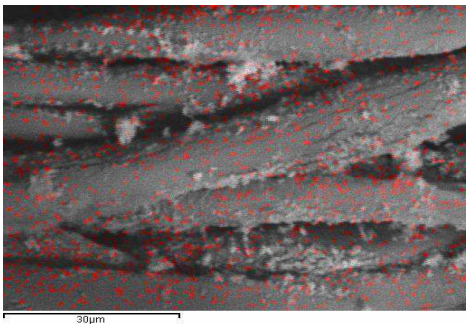


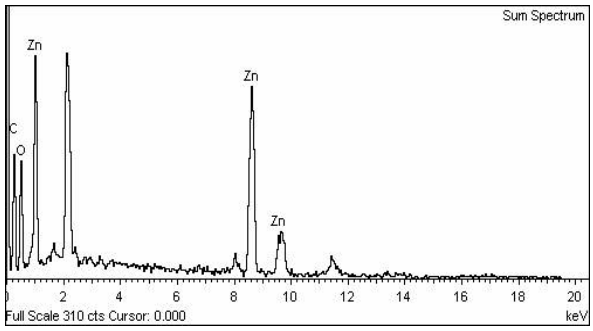
(c) **(d)**



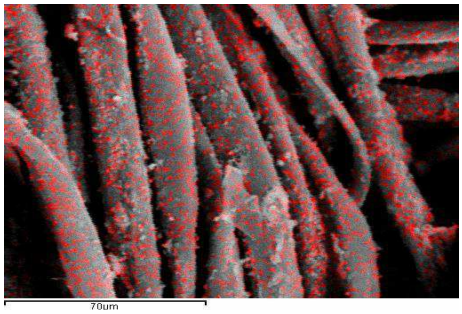
(e)

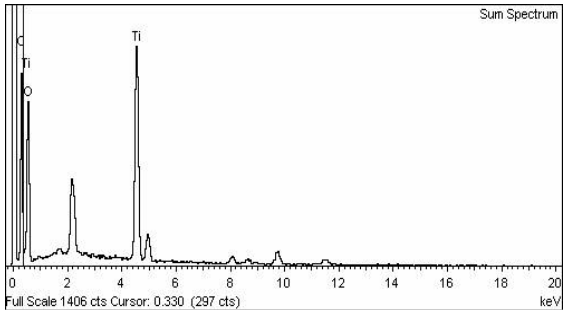
Figure (3): SEM micrographs of TiO_2, TiO_2+binder, Pre-loaded with TiO_2 posted-coated with chitosan+, Pre-coated with chitosan+alginate post-loaded with TiO_2, chitosan+alginate+TiO_2 mixture coated fabrics. (a) TiO_2 loaded fabric; (b) TiO_2+binder coated fabric; (c) Pre-loaded with TiO_2 posted-coated with chitosan+alginate fabric; (d) Pre-coated with chitosan+alginate post-loaded with TiO_2 fabric; (e) chitosan+alginate+TiO_2 mixture coated fabric





(a)





(b)

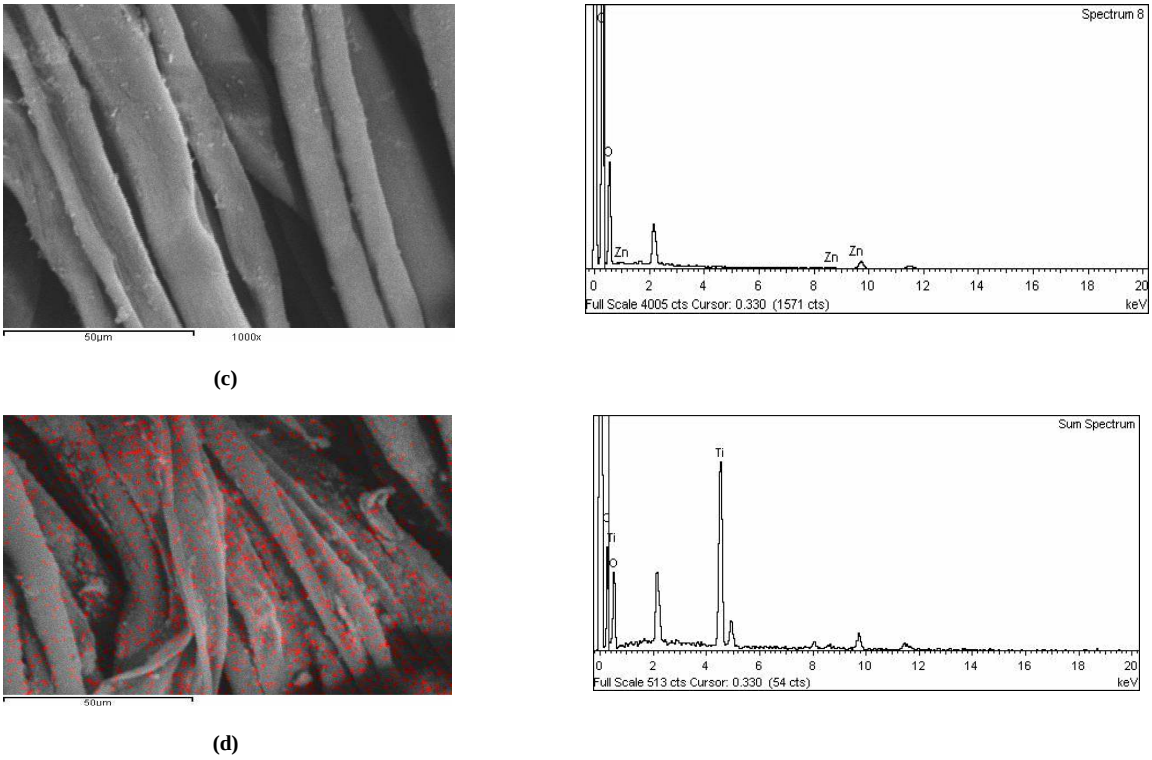


Figure (4): EDX micrographs of ZnO, TiO_2, Pre-loaded with ZnO posted-coated with chitosan-alginate, Pre-loaded with TiO_2 posted-coated with chitosan-alginate fabrics
(a) ZnO loaded fabric (Zn weight= 26.37 %), (b) TiO_2 loaded fabric (Ti weight= 14.74 %), (c) Pre-loaded with ZnO posted-coated with chitosan-alginate fabric (Zn weight= 0.65 %), (d) Pre-loaded with TiO_2 posted-coated with chitosan-alginate fabric (Ti weight= 10.7 %)

In case of chitosan+alginate+ZnO and chitosan+alginate+TiO_2 mixtures coated fabrics, the metal oxides particles may be imbedded into the PEC polymer system which may prevent metal oxide particles from showing independently on the fabric surface. It should be noted that ZnO and TiO_2 content determined by EDX is always different from the actual amounts on the materials which may be attributed to EDX technique analysis of the fiber surface otherwise metal particles may be penetrated and physically trapped between the fibers.

4.2. Antibacterial properties

The blank, chitosan+alginate polymer; in presence and absence of ZnO, TiO_2, binder coated samples were subjected to assessment the antibacterial efficiency against gram negative bacteria *E. coli* and gram positive bacteria *S. aureus.* The antibacterial activities of coated samples were mentioned in Table (1) and discussed as follow:

I. Generally, there are differences in reduction percent (%) between the two types of assessed bacteria regardless the treatment type. The reason for these variations is probably due to the differences in the cell walls i.e. *E. coli* has thinner and slack cell walls, and the sensitivity to the finishing agents and/or types [5,16].

II. The antibacterial activity results of samples coated with chitosan showed very good bacterial reduction efficiency, 68% for *E. coli* and 64% for *S. aureus*. These results may be due to the antibacterial activity of chitosan that is assigned to the amino groups, which in acidic media form ammonium salts [17]. There are two mechanisms proposed for chitosan antibacterial activity. The first; its polycationic nature interferes with bacterial metabolism by stacking the cells' surface. The second mechanism is binding between chitosan and DNA to inhibit mRNA synthesis [18].

III. On the other hand it was obvious from the results that samples coated with alginate only achieved fair antibacterial efficiency; 38% for *E. coli* and 32% for *S. aureus* bacteria. This may be attributed to that alginate has mild antiseptic, hemostatic, and antibacterial properties as well as the ability to promote wound healing [19,20].

IV. There is an increase in antibacterial activity of samples treated with chitosan+alginate mixture; the reduction achieved 75% and 73% for *E. coli* and *S. aureus* respectively. When mixing chitosan with alginate it creates a polyelectrolyte complex (PEC) of oppositely charged polymers which have the advantages when applied as coating material for textile fabrics [13]. Consequently, enhancement of antibacterial efficiency of the polymer-coated samples.

V. The samples coated with ZnO only achieved 79% with *E. coli* and 78% reduction with *S. aureus* bacteria. In addition, in case of coating samples with TiO_2 the results were 79% and 71% reduction for *E .coli* and *S. aureus* respectively. These results may be attributed to the antibacterial activity of Zn and Ti metal ions [21]. Metals and

metal ions are toxic to microbes at very low concentration either in free state or in compounds. They kill microbes by binding to intracellular proteins, DNA, and lipids damaging them [8]. Whereas, the antibacterial efficiency slightly increased in case of mixing ZnO and TiO_2 with the binder, ZnO and TiO_2 are supported by the reaction with functional groups of the binder which cross-linking the whole system on fabric surface [22].

VI. The chitosan+alginate+ZnO and chitosan+alginate+TiO_2 mixtures improved the antibacterial efficiency of the coated samples for both types of bacteria. The maximum antibacterial reduction % was achieved with pre-loaded with metal oxides post-coated with chitosan+alginate mixture giving 90% and 87% in case of fabrics pre-loaded with ZnO post-coated with chitosan+alginate mixture; 92% and 89% in case of fabrics pre-loaded with TiO_2 post-coated with chitosan+alginate mixture for *E. coli* and *S. aureus* respectively. These results may be attributed to the dual action of Zn and Ti metal ions which loaded and physically trapped firstly to the fabric, in addition to applying chitosan+alginate (PEC) polymer creating another layer of protective coating film which in turn increases the antibacterial efficiency [23].

Table (1): Bacterial reduction % of chitosan, alginate, ZnO, and TiO_2 coated fabrics

Treatment Type	*Bacterial Reduction %*	
	Escherichia coli (g.n.b.)	***Staphylococcus Aureus (g.p.b)***
Blank	0%	0%
Chitosan	68%	64%
Alginate	38%	32%
Chitosan+alginate mixture	75%	73%
ZnO	79%	78%
ZnO + binder	82%	81%
ZnO+chitosan+alginate mixture	85%	82%
Pre-loaded with ZnO post-coated with chitosan+alginate mixture	90%	87%
Pre-coated with chitosan+alginate mixture post-loaded with ZnO	86%	84%
TiO_2	79%	71%
TiO_2 + binder	81%	73%
TiO_2+chitosan+alginate mixture	87%	84%
Pre-loade with TiO_2 post-coated with chitosan+alginate mixture	92%	89%
Pre-coated with chitosan+alginate mixture post-loaded with TiO_2	84%	83 %

g.p.b.: Gram-positive bacteria; g.n.b.: Gram-negative bacteria.

4.3. Ultraviolet Protection Factor (UPF)

UV protection is mainly determined by fiber type and hence chemical composition; fabric construction; additives; textile processing aids; fabric finish and color [24].According to AS/NZS 4399:1996 the protection categories are; non ratable protection UPF <15, good protection UPF>15, very good protection UPF>30, and excellent protection UPF>40, 50, 50+. The rate of UV protection of cotton fabrics was quantified and expressed via UPF values that are given in Table (2). It is suggested that UPF of apparel and garment application should be at least 40 to 50+.

Chitosan+alginate mixture (PEC) polymer increase the UPF value but didn't improve the protection category. This may be due to they created a transparent film on fabric which allowed UV rays to transmit through their surface, in addition to treatment cotton fabrics with chitosan doesn't have great effect on UV-blocking function [25].

Generally, inorganic UV blockers such TiO_2 and ZnO have unique features such as; non-toxicity and chemical stability under high temperature and UV-rays exposure. There provide good protection by reflecting and/or scattering most of the UV-rays, additionally they absorb UV radiation because of their semi conductive properties [26]. So after cotton fabrics treated with TiO_2 and ZnO either alone or in mixtures, the UV-blocking properties of treated fabrics improved greatly. The UPF values for all coated fabric in this study achieved good to excellent protection categories as shown in Table (2). The UPF values in these figures clearly showed that the minimum UPF values were >30 (very good protection) achieved with pre-loading cotton fabric with metal oxides post-coating with chitosan+alginate (PEC) polymer for both TiO_2 and ZnO. This may be due to chitosan+alginate polymer created a layer covered the metal oxide particles from being on the fabric surface as well as reflect and/or scatter and absorb UV radiation which agree and explained in the conversely case achieving excellent protection category 50+ (88 for ZnO and 325 for TiO_2). On the other hand the UPF values were decreased but still achieved excellent protection >40 (45 for ZnO and 65 for TiO_2) in case of coating fabric with metal oxides+chitosan+alginate mixtures in one bath for both types of metals (TiO_2 and ZnO).

The excellent UV protection achieved with metal oxides (TiO_2 and ZnO) treatment either alone or in mixtures. These results may be attributed to metal oxides particles were physically trapped and covered the entire fabric surface, results more area for diffuse reflection, scatting, and absorption of UV radiation [26,27]. Meanwhile, UPF values insignificantly decreased while maintained the excellent protection category 50+ (123 for ZnO and 241 for

TiO_2) in case of coating fabric with metal oxides+binder mixtures for both metal types. These results may be attributed to the prepared mixtures would induce the aggregation of metal oxides particles which appeared in the SEM images, thus producing a lower scattering efficiency [28].

Table (2): Ultraviolet protection factor (UPF) of chitosan, alginate, ZnO, and TiO_2 coated fabrics

Treatment Type	Ultraviolet Protection Factor (UPF)
Blank	5
Chitosan	12
Alginate	7
Chitosan+alginate mixture	15
ZnO	50+ (185)
ZnO + binder	50+ (123)
ZnO+chitosan+alginate mixture	45
Pre-loaded with ZnO post-coated with chitosan+alginate mixture	32
Pre-coated with chitosan+alginate mixture post-loaded with ZnO	88
TiO_2	50+ (390)
TiO_2 + binder	50+ (241)
TiO_2+chitosan+alginate mixture	50+ (65)
Pre-loade with TiO_2 post-coated with chitosan+alginate mixture	44
Pre-coated with chitosan+alginate mixture post-loaded with TiO_2	50+ (325)

4.4. Wettability properties

The results of water absorption measurements are given in Table (3). The results showed that the water absorbency of coated cotton fabrics irrespective to the treatment type, enhanced significantly according to the standard test method (zero) after treatment. This may be due to the hydrophilic nature of alginate itself as well as the presence of zinc and titanium ions which accelerated high moisture absorption as well as diffusion into fibers; trigger swelling and absorbed within fibers [23]. The difference in coated fabrics absorption may be explained with the phenomenon that all prepared treatment solutions diffuse into fibers, trigger swelling and absorbed by within fibers specially alginate. Whereas, in case of treatment cotton fabric with chitosan alone, water absorbency didn't affected; taking more than 60 seconds (60+s); which could be discussed in terms of its ability to encapsulate the cotton fibers as well as to coat the surface with a thin film, hence the diffusion of water molecules into fabric surface and fibers require longer time [29,30].

Table (3): Wettability for different treated samples according to AATCC Absorbency of Textiles test method

Treatment Type	Absorption Time (second)
Blank	60+ s
Chitosan	60+ s
Alginate	Zero
Chitosan+alginate mixture	Zero
ZnO	Zero
ZnO+binder	Zero
ZnO+chitosan+alginate mixture	Zero
Pre-loaded with ZnO post-coated with chitosan+alginate	Zero
Pre-coated with chitosan+alginate post-loaded with ZnO	Zero
TiO_2	Zero
TiO_2+binder	Zero
TiO_2+chitosan+alginate mixture	Zero
Pre-loaded with TiO_2 post-coated with chitosan+alginate	Zero
Pre-coated with chitosan+alginate Post-loaded with TiO_2	Zero

4.5. Healing and anti-inflammatory properties

I. The subplanter injection of 100µL of 1% sterile carrageenan into the rat hind paw elicited an inflammation (swelling and erythema) and a time-dependent increase in paw oedema by 44.49, 52.42 and 53.30% at 1st, 2nd and 3rd

hours respectively, and the paw thickness was maximal by 59.91% at 4h post-carrageenan injection as compared with pre-carrageenan control values.

II. The results of fabrics coated with alginate or chitosan individually showed non-significant inhibition of oedema formation at 1st and 2nd hours respectively, while induced a significant oedema inhibition by 3.62 and 4.13 % after 3rd hour and 28.97 and 29.97 % after 4th hour respectively. Meanwhile fabrics coated with chitosan+alginate mixture induced a significant oedema inhibition by 31.93, 45.72, 46.95 and 78.97% at 1st, 2nd, 3rd and 4th hours respectively, as compared with carrageenan control group at the same time post carrageenan injection; shown in Figure (5). Where, data represent the mean value ± S.E. of six rats and % increase in oedema paw thickness. Data were analyzed using one way ANOVA and LSD comparison test.* Significantly different from carrageenan control value at respective time point at P<0.05.

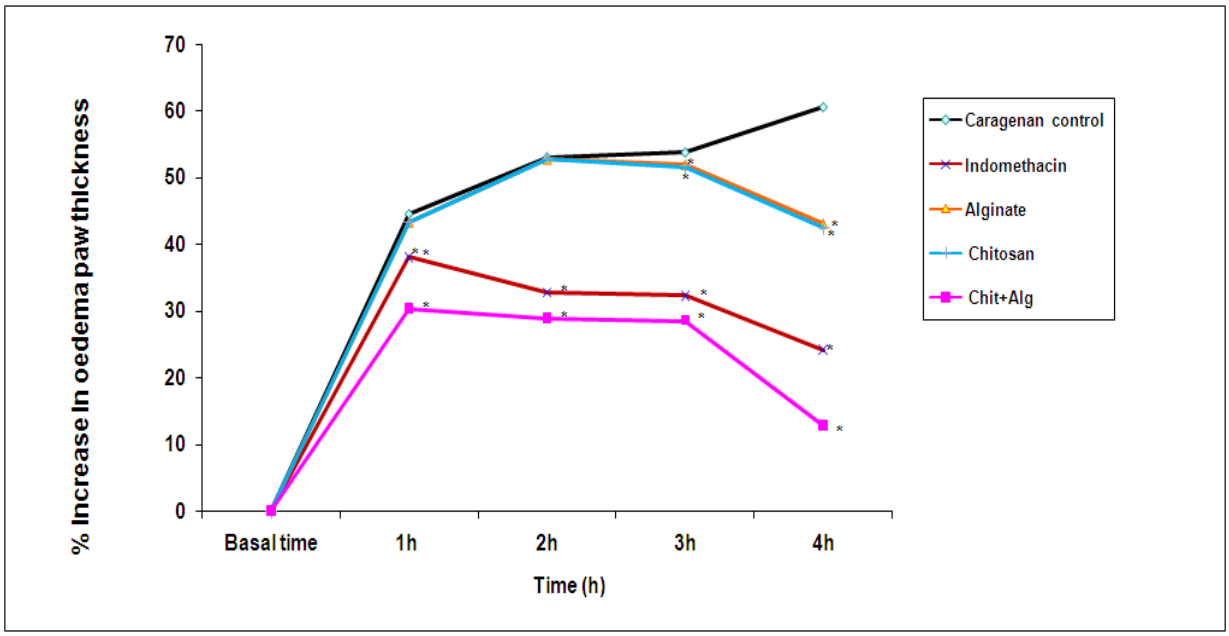


Figure (5): Time course of the effects of cotton fabrics coated with alginate and/or chitosan on rat paw oedema thickness induced by sub-plantar injection of 1% carrageenan

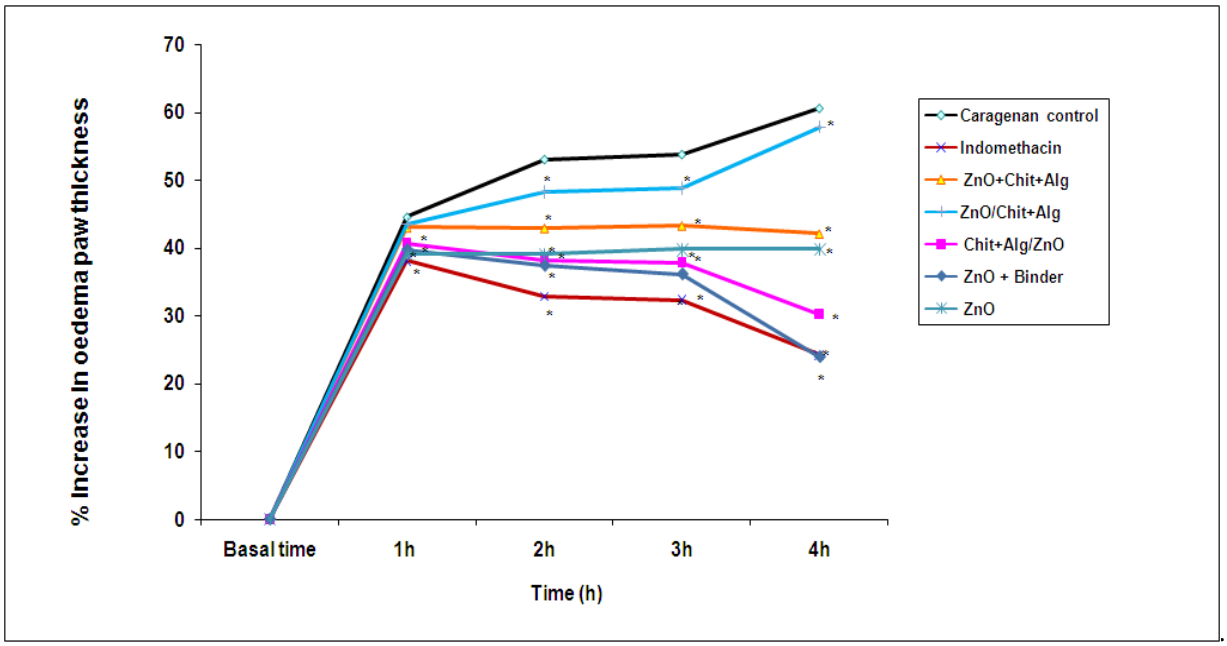


Figure (6): Time course of the effects of ZnO+chitosan+alginate mixture, pre-loaded with ZnO post-coated with chitosan+alginate, pre-coated with chitosan+alginate post-loaded with ZnO, ZnO+binder or ZnO coated fabrics on rat paw oedema thickness induced by sub-plantar injection of 1% carrageenan

III. Fabrics coated with ZnO+chitosan+alginate mixture or pre-loaded with ZnO post-treated with chitosan+alginate mixture showed non-significant inhibition of oedema formation at 1st hour while ZnO+chitosan+alginate mixture induced significant oedema inhibition by 19.07, 19.50 and 30.50 % at 2nd, 3rd and 4th hours respectively, similarly pre-loaded with ZnO post-treated with chitosan+alginate mixture induced significant oedema inhibition by 9.16, 9.32 and 4.64 % at 2nd, 3rd and 4th hours respectively. Meanwhile pre-coated fabric with chitosan+alginate mixture post-loaded with ZnO; coated fabric with ZnO+binder mixture; or ZnO individually; showed a significant oedema inhibition by 8.66, 10.84 and 12.48% at 1st hour, 28.08, 29.52 and 26.37% at 2nd hour, 29.75, 32.79 and 26.18% at 3rd hour as well as and 50.03, 60.47 and 34.34% at 4th hour respectively, as compared with carrageenan control group at the same time post carrageenan injection; shown in Figure (6). Where, Data represent the mean value ± S.E. of six rats and % increase in oedema paw thickness. Data were analyzed using one way ANOVA and LSD comparison test.* Significantly different from carrageenan control value at respective time point at $P<0.05$.

These results could be explained according to the fact that ZnO helps to restore the disturbed skin-barrier function in eczematous diseases and enhances wound healing, it considered safe to use, since it does not penetrate the skin, even with disturbed barrier function. Moreover, ZnO has excellent anti-inflammatory, drying, mild astringent and antiseptic properties, it plays a major role in wound healing by enhancing the wound healing process by delivering zinc ions to the wound and allowing them to remain there for an extended period of time [31].

IV. Coated fabric with TiO_2+chitosan+alginate mixture showed non-significant inhibition of oedema formation at 1st, 2nd and 3rd hour while induced significant oedema inhibition by 13.65 % at 4th hours. Meanwhile pre-loaded fabrics with TiO_2 post-coated with chitosan+alginate mixture or pre-coated with chitosan+alginate mixture post-loaded with TiO_2 showed a significant oedema inhibition by 7.59 and 3.70% at 1st hour, 28.45and 21.16% at 2nd hour, 30.60 and 25.43% at 3rd hour as well as 55.41 and 44.60% at 4th hour respectively, also coated fabrics with TiO_2+binder mixture or TiO_2 individally showed a significant oedema inhibition by 7.84 and 5.35% at 1st hour, 16.59 and 6.35% at 2nd hour, 17.52 and 7.65 at 3rd hour as well as 26.25 and 20.28% at 4th hour respectively, as compared with carrageenan control group at the same time post carrageenan injection; clearly showed in Figure (7). Where, Data represent the mean value ± S.E. of six rats and % increase in oedema paw thickness. Data were analyzed using one way ANOVA and LSD comparison test.* Significantly different from carrageenan control value at respective time point at $P<0.05$.

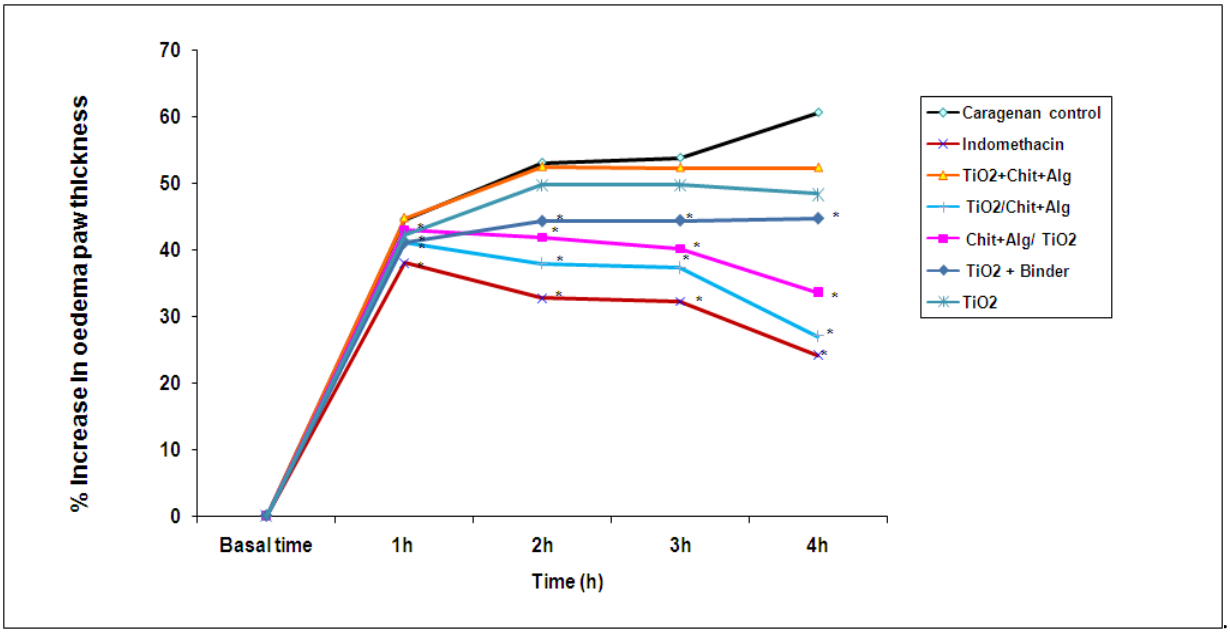


Figure (7): Time course of the effects of TiO_2+chitosan+alginate mixture, pre-loaded with TiO_2 post-coated with chitosan+alginate, pre-coated with chitosan+alginate post-loaded with TiO_2, TiO_2+binder or TiO_2 coated fabrics on rat paw oedema thickness induced by sub-plantar injection of 1% carrageenan

V. Treated fabrics with indomethacin (1%) showed significant inhibition of oedema formation by 14.51, 38.20, 39.96 and 60.08% at 1st, 2nd, 3rd and 4th hours respectively, as compared with carrageenan control group at the same time post carrageenan injection; shown in Figure (5).

By comparing the results of all coated fabrics with indomethacin, results revealed that coated fabric with chitosan+alginate mixture achieved the most anti-inflammatory activity exceeding the fabrics treated with indomethacin. It has also been stated that dressings from alginates have haemostatic properties and can accelerate wound healing. Meanwhile, the biological activity of chitosan has its basis in its ability of enzymatic degradation in the presence of lisozyme, the enzyme included in body fluids, thanks to which the bio-active oligomers of N-acetylo-D-glucosoamine and D-glucosoamine are created. It was stated that hexamines, to which group N-acetylo-D-glucosoamine also belongs, facilitate the wound's granulation, and at the same time accelerate and stimulates the process of wound healing without irritation or allergization. Such composite structures have applications in management of burns, bedsores, skin ulcer, hard-to-heal wounds as well as wounds requiring frequent dressing change [19,32].

CONCLUSION

In the present research woven cotton fabric was used to develop multipurpose textiles. Biopolymer such as chitosan, sodium alginate, as well as TiO_2, ZnO and their mixtures were prepared and used for coating by pad-dry technique. The results obtained from SEM and EDX analysis showed changing in surface morphology of coated fabrics, which indicated that good amount of polymer and metal oxides were coated and loaded on the fabric. *Escherichia coli* and *Staphylococcus aureus* were used to investigate the antibacterial activity. The results showed that all coated fabrics in this study posses good to excellent bacterial reduction % regardless of the mixture type and the maximum values were found in case of coating with mixtures of chitosan+alginate+TiO_2 (92%) reduction and chitosan+alginate+ZnO (90%) reduction. Additionally, UV-blocking properties of coated fabrics showed good to excellent protection category (40-50+), which achieved when incorporating TiO_2 and ZnO with chitosan and alginate. The wettability properties of all coated fabrics showed an enhancement except chitosan coating which unchanged compared with blank fabric. Furthermore, healing ability of coated fabrics was estimated using the carrageenan-induced rats paw oedema test and showed enhancement in healing and anti-inflammatory activity for all coating mixtures, and the strongest healing activity was achieved in chitosan+alginate mixture. Hence, these coated fabrics attain multifunctional properties for concurrent medical and industrial applications.

REFERENCES

[1] S Petrulyte, *Danish Medical bulletin*, **2008**, 55(1), 72-77.
[2] D Mihailovic´; Z Šaponjic´; M Radoicˇic´; T Radetic´; P Jovancˇic´; J Nedeljkovic´; M Radetic, *Carbohydrate Polymers*, **2010**, 79(3), 526-532.
[3] R Rai; CR Srinivas, *Indian J. Dermatol. Venereol. Leprol.*, **2007**, 73(2), 73–79.
[4] H Yang; S Zhu; N Pan, *Journal of Applied Polymer Science*, **2004**, 92(5), 3201–3210.
[5] M Shateri-Khalilabad; M E Yazdanshenas, *Textile Research Journal*, **2013**, 83(10), 993-1004.
[6] G Sun; KH Hong, *Textile Research Journal*, **2013**, 83(5), 532-542.
[7] M Miraftab; J Barnabas; JF Kennedy; R Masood, *Journal of Industrial Textiles*, **2011**, 40(4), 345-360.
[8] Y Gao; R Cranston, *Textile Research Journal*, **2008**, 78(1), 60–72.
[9] A Elshafei; HT Elzanfaly, *Asian Journal of Applied Sciences*, **2011**, 4, 585-595.
[10] Y Qin, *International Wound Journal*, **2005**, 2(2), 172-176.
[11] CH Goh; PW Heng; LW Chan, *Carbohydrate Polymers*, **2012**, 87(2), 1796– 1802.
[12] LF Zemljic; O Sauperl; I But; A Zabret; M Lusicky, *Textile Research Journal*, **2011**, 81(11), 1183-1190.
[13] OL Shanmugasundaram and RVM Gowda, *Journal of Industrial Textiles*, **2012**, 42(2), 156-175.
[14] CA Winter; EA Risley; GW Nuss, *Proc. Soc. Exp. Biol. Med*., **1962**, 111, 544-52.
[15] MG Obukowicz; DJ Welsch; WJ Salsgiver; CL Martin-Berger; KS Chinn; KL Duffin; A Raz; P Needleman, *J. Pharmacol. Exp. Ther*., **1998**, 287(1), 157-66.
[16] D Hua; K Cheuk; Z Wei-ning; W Chen; X Chang-fa, *Transactions of Nonferrous Metals Society of China*, **2007**, 17, 700-703.
[17] NV Majeti, R Kumar, *Reactive & functional Polymers*, **2000**, 46, 1-27.
[18] T Ristić1; LF Zemljič; M Novak1; MK Kunčič1; S Sonjak; NG Cimerman; S Strnad, *Science against microbial pathogens: Communicating current research and technological advances*, **2011**, 1(3), 36- 51.
[19] B Gupta; R Agarwal; MS Alam, *Indian Journal of Fibre & Textile Research*, **2010**, 35, June, 174-187.
[20] J Sun; H Tan, *Materials*, **2013**, 6, 1285-1309.
[21] B Simoncic; B Tomsic, *Textiles Research Journal*, **2010**, 80(16), 1721-1737.
[22] V Čechalová; A Kalendová, *Journal of Physics and Chemistry of Solids*, **2007**, 68, 1096-1100.
[23] T Mikołajczyk; D Wołowska-Czapnik, *FIBRES & TEXTILES in Eastern Europe*, **2005**, 13, 3(51), 35-40.
[24] YL Lam; CW Kan; CW Yuen, *Textile Research Journal*, **2010**, 81(14), 1419–1426.
[25] X Chen; Y Liu; H Shi; X Wang; K Qi1; X Zhou; JH Xin, *Textile Research Journal*, **2010**, 80(20), 2214–2222.
[26] H Yang; S Zhu; N Pan, *Journal of Applied Polymer Science*, **2004**, 92(5), 3201-3210.

[27] BR Das, *The Open Textile Journal*, **2010**, 3, 14-21.
[28] CH Xue; ST Jia; HZ Chen; M Wang, *Science and Technology of Advanced Materials*, **2008**, 9(3), 1-5.
[29] YS Chung; KK Lee; JW Kim, *Journal of Textile Research*, **1998**, 68(10), 772-775.
[30] Y Shin; DI Yoo; J Jang, *Journal of Applied Polymer Science*, **2001**, 80(13), 2495-2501.
[31] C Wiegand; UC Hipler; S Boldt; J Strehle; U Wollina, *Clinical, Cosmetic and Investigational Dermatology*, **2013**, 6, 115–121.
[32] W Stęplewski; D Wawro; A Niekraszewicz; D Ciechańska. *FIBRES & TEXTILES in Eastern Europe*, **2006**, 14, 4(58), 25-31.