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Antimicrobial and UV protection finishing of Polysaccharide -Based Textiles using Biopolymer and AgNPs

Mohamed A. Ramadan*[1], Ghada M. Taha[1], Walaa Zein EL- Abedin EL- Mohr[2]
[1]*Textile Research Division, National Research Centre (ID: 60014618), Egypt.*
[2]*Home Economics Department (Clothes and Textile Branch) - Faculty of Specific Education - Tanta University*

THIS article was concentrated on the preparation of antimicrobial and protective cellulosic fabrics based polysaccharides material by natural macromolecule and carbohydrate biopolymer such as chitosan. This study also addressed the application of nanotechnology in achieving this purpose using silver nanoparticles (AgNPs). Chitosan and AgNPs were also used in the treatment bath to improve some functional properties of these fabrics. Some investigations were performed for the treated fabrics such as ultra violet protection factor (UPF), contact angle, air permeability, water permeability, antimicrobial activity for four types of microbes namely Pseudomonas aerugenosa (P), Staphylococcus aureus (S), Aspergillus niger (A) and Candida albicans (C), tensile strength and elongation at break, scanning electron microscopy (SEM) and FT-IR. Cellulosic fabrics with three constructions were used in this research (Shibeka Hunycomb and Crepe). The results showed that fabrics treated with chitosan gave the best result for resistance to microbes and UPF and this led to reduction in air permeability and water absorbance regardless of the type of construction of the treated fabric. From the above, these fabrics can be used in the various purposes such as medical field and protection fabrics from UV rays.

Keywords: Polysaccharides, AgNPs, chitosan, Antimicrobial, UV rays protection.

Introduction

Cotton, the most abundantly available natural fibre, possesses many functional properties such as high moisture regain with good absorbency, adequate strength, comfort feel during wear and easy dye ability which act as the carriers for microorganisms, such as pathogenic and odour generating bacteria, mould and fungi causing damage to clothing, strength loss, staining, discoloration and may even cause skin diseases. In cotton under certain conditions the presence of carbohydrates acts as nutrients and energy source to microbes. Various other sources of nutrients for microorganisms are soil, dust, solutes from sweat and some textile finishes [1, 2]. Antimicrobial finishes maintain hygiene and enables to avoid infection from pathogens especially in hospitals, nursing homes, schools, hotels, and crowded public areas. They prevent unpleasant odour on intimate apparel, underwear, socks and athletic wear. Microbes attack natural fibres because they are hydrophilic in nature. Antimicrobials agents are protective agents that, being bacteriostatic, bactericidal, fungistatic and fungicidal such as Quaternary ammonium, triclosan, metallic salt, and chitosan. Chitosan has antimicrobial activity towards microorganisms, such as bacteria, yeast, and fungi due to its positive charges in acidic pH [3-8]. Nanosized inorganic and metal oxides particles possess high surface area/volume ratio and display unique physical and chemical properties. Silver containing products are also interesting materials for wound repair applications. When metallic silver reacts with moisture on the skin surface or with wound fluids, silver ions are released, damaging bacterial RNA and DNA, thus inhibiting replication. Sustained silver release products have a bactericidal action and manage wound exudates and odor [9-17] .

On the other hand, UV resistance in textiles

*Corresponding author e-mail: amaramadan1@hotmail.com
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refers to a fibre's ability to resist UV radiation. The UV resistance of textiles achieved through the combination of fibre selection and engineering of the fabric construction or by adding particular additives to the fibre such as titanium oxide[15,16] or carbon black or zinc oxide [18,19]. The fabric characteristics such as density, weight, weave; swilling and color have affected on UV resistance. Adding materials to the fabric led to film formation on the fabric surface which reduces UV penetration by reflecting, absorbing and/ or scattering the radiation. Incorporation of UV resistance particles to the synthetic fibre structure at the fibre production stage increase protection. This approach will due to the wide range of factors that influence textiles UV protection. So adding additives approach should be study [20-23].

This work is devoted to studying the effect of chitosan and silver nanoparticles on function properties of different cotton constructions fabrics (shibeka, honeycomb and crepe) such as antimicrobial activity, ultra violet protection rays in addition to water permeability, contact angle, air permeability and some mechanical properties. In this paper, we tried to find out whether the fabric constructions (surface nature of Polysaccharide -Based Textiles) affects the functional properties of the materials used, this point is the novelty of this manuscript.

Materials and Methods

Materials

Different constructions cotton fabrics (shibeka, honeycomb and crepe) were kindly supplied by Misr Co. for Spinning and Weaving, Elmehalla Elkubra, Egypt. Chitosan, low molecular weight, Brookfield viscosity 40,000 cps, was kindly supplied by Aldrich Chemical (Germany). Citric acid , sodium hypophosphite and silver nanoparticles (AgNPs) powder were also purchased from Aldrich Chemical (Germany). All these chemicals used were of laboratory grade.

Preparation of chitosan slurry & AgNPs Suspension

In a conical flask dissolve 5% citric acid and add chitosan (2, 4, 6 gm/l), all this system will put under magnetic stirring till complete dissolution of chitosan. At Another flask add 0.1 gm of AgNPs powder with Ethylene glycol (2gm/l), finally AgNPs suspension was formed.

Treatment of cotton fabric:

Cotton fabrics with different constructions were treated in two separate steps as follows:

a- *Treatment of cotton fabrics with chitosan :*

The bleached cotton fabrics was dipped in chitosan solution for 10 minutes and then squeezed to 100% wet pickup at constant pressure, then all samples were dried for 4 min. at 80 °C and cured for 2 min. at 140 °C.

b- Treatment of cotton fabrics with silver nanoparticles:

The bleached fabrics were treated with AgNPs suspension (100,200&300 ppm) and squeezed to 100% wet pickup at constant pressure and then dried at 80^0C for 3minutes and cured for 2 minutes at 140^0C.

Characterization technique

Ultra Violet Protection Factor (UPF)

UPF of the samples was measured according to the ATTCC183:2010 method through Jasco V-750 Spectrophotometer.

Fourier transforms infra-red (FT-IR)

The FTIR spectra of the samples were recorded by using an FT- IR spectrophotometer (Jasco FT-IR 4700) in the region of 4000-400 cm-1 with spectra resolution of 4 cm^{-1}

Contact angle

Contact angle of the treated fabrics samples was determined by data physics instrument (OCA 15 EC) Gmbh, contact angle measured by horizontal plate camera perpendicular to liquid droplet plane.

Tensile strength and elongation at break

They were determined according to ASTM, Standard Test Method, D-1682-94 (1994).

Water Absorbency

It was measured by the Toyoseik –japan by standered method ASTMD-583.

Air permeability

It was measured by the Toyoseik -japan by standered method ASTMD-737.

Antibacterial activity (Agar Plate Method)

All antibacterial activity tests were done in triplicate to ensure reproducibility. The antibacterial activity of fabric samples was evaluated against Pseudomonas aerugenosa (P),Staphylococcus aureus (S), Aspergillus niger (A) and Candida albicans (C), (ATCC 1533) bacteria using disk diffusion method. A mixture of nutrient broth and nutrient agar in 1 L distilled water at pH 7.2 as well as the empty Petri plates were autoclaved. The agar medium was then cast into the Petri plates and cooled in laminar airflow.

Approximately 105 colony-forming units of E. coli bacteria were inoculated on plates, and then 2.92 cm^2 of each fabric samples was planted onto the agar plates. All the plates were incubated at 37°C for 24 h and examined if a zone of inhibition was produced around samples.

Scanning Electron Microscopy Measurements

Microscopic investigations on fabric samples were carried out using a Philips XL30 scanning electron microscope (SEM) equipped with a LaB6 electron gun. Fabric samples were fixed with carbon glue and metalized by gold vapor deposition to record images.

Results and Discussion

Ultra Violet protection factor

The effect of treatment of different constructions fabrics by using different concentrations of chitosan and AgNPs were evaluated by measuring UPF value, the data are presented in table 1.

From table 1 UPF value for all treated samples increases with increasing the concentration of treatment material regardless construction type. This behavior may be due to increase the film thickness of finishing material (chitosan) which prevents UV rays from passing through fabrics and have efficient to scattering UV rays. The UPF value depends on the weave fabric structure and concentration of treatment material. AgNPs are a good anti-UV finish through the above results in table 1 due to high UV absorption capacity of silver nanoparticles. All these findings are in harmony with some earlier reported results [23].

Contact angle of the treated fabrics

The effect of chitosan concentration on the contact angle of the different fabrics constructions was evaluated as Shown in table 2.

From table 2, it is obvious that, 6% concentration of chitosan gave the highest contact angle; the contact angle increases by increasing the concentration of chitosan for three fabric constructions. It is worth noting that chitosan is partially soluble in water and therefore using a high concentration of it can lead to the formation of a film on the surface of the fabric that reduces the absorption of the fabric by water. On the other hand the highest quantity of chitosan do not penetrates fabric fibers, so it makes thick film on the fabric surface which prevent water absorption, so the higher concentration of chitosan led to increasing in contact angle between the fabric and water drops. While table 3 Shows the effect of silver nanoparticles on contact angle of the treated samples. It is seen that the treatment of the fabrics by AgNPs has no effect on the contact angle of fabrics. This behavior is come back to the fact that silver nanoparticles do not form a film on the fabric surface that prevents water from passing through the fabric fibers.

As general Crepe construction gave good results than the other constructions (Shibeeka and Hunycomb) for contact angle and UPF in presence of chitosan and AgNPs. This behavior may be attribute to this structure has a higher absorption power towards the treatment materials.

Antimicrobial Activity

Fig. 1 shows the antibacterial properties of different constructions fabrics treated with chitosan. It disclosed that the treated fabrics have antimicrobial activity at all chitosan concentrations for all microbe types. The crepe construction is the most resistant to microbial growth because It has the highest absorption power towards chitosan and this is consistent with the contact angle measurements.

Fig. 2 showed that dependence of the antimicrobial activity of treated fabrics on AgNPs concentration and fabric construction type. It illustrated that AgNPs concentration plays a rule in inhibition zone diameter values for all microbe types and fabric construction also. AgNPs are

TABLE 1. UPF value of treated fabrics with different concentration of chitosan and AgNPs .

Fabric Construction	UPF value							
	Chitosan concentration (g/l)				AgNPs concentration (ppm)			
	0	2	4	6	0	100	200	300
Shibeka	2.1	27	35	39	2.1	31	32	35
Hunycomb	2.7	27	36	43	2.7	32	34	38
Crepe	2.3	31	40	47	2.3	40	44	51

TABLE 2. Effect of chitosan concentration on contact angle of the treated fabrics.

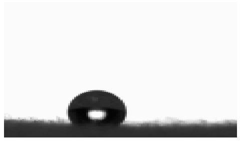
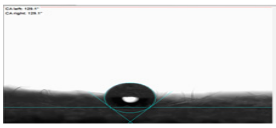
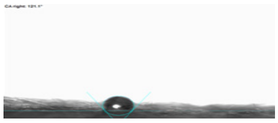
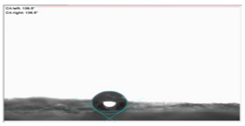
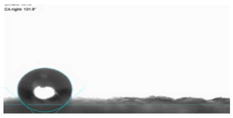
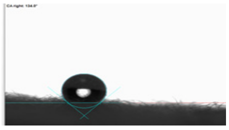
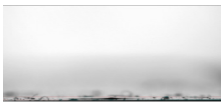
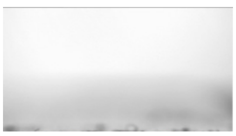
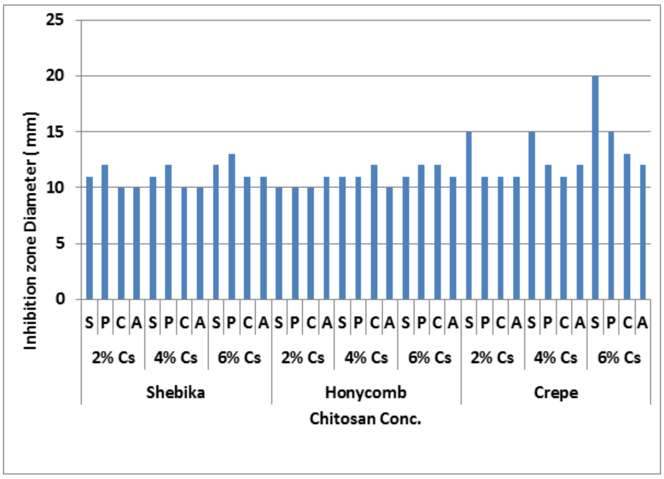
Chitosan Conc. w/v (%)	Contact angle (°)		
	shibeka	**Hunycomb**	**Crepe**
0			
2	126 	109 	126 
4	129 	121 	133 
6	137 	132 	134 

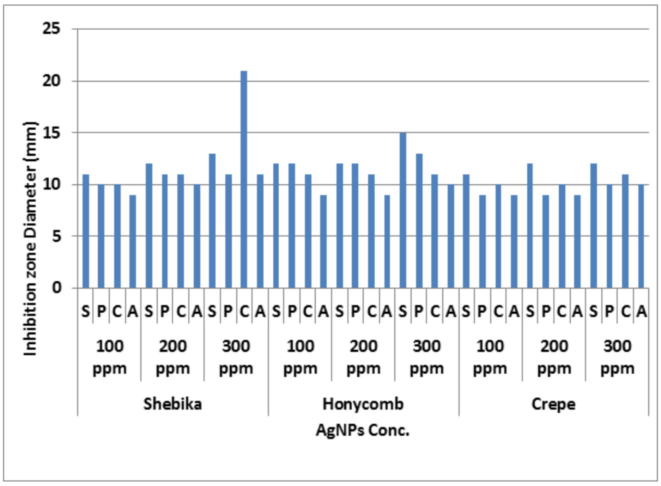
TABLE 3. Effect of AgNPs concentration on contact angle of the treated fabrics.

[AgNPs] (ppm)	Contact angle (^{0})		
	shibeka	**Hunycomb**	**Crepe**
0			
100	0 	0 	0 
200	0 	0 	0 
300	0 	0 	0 



*NB : Inhibition zone diameter of untreated fabrics= zero mm

Fig. 1. The antibacterial properties of different constructions fabrics treated with chitosan.



*NB : Inhibition zone diameter of untreated fabrics equal zero mm

Fig. 2. Effect of AgNPs concentrations on antimicrobial properties of treated fabrics.

physically bonded with cotton fabrics during treatment process (13).

Physical and mechanical properties of the treated fabrics

The changes in some physical and mechanical properties of the treated fabrics with different concentrations of chitosan or silver nanoparticle (AgNP) were evaluated by monitoring the tensile strength, water permeability, air permeability and elongation at break.

Table 4 showed that some of physical and mechanical such as water permeability, air permeability, tensile strength and elongation at break of the treated fabrics were affected by chitosan concentration as follow, water permeability (negative property) and air permeability decreased by increasing treatment material concentration , while tensile strength and elongation at break increased with increasing concentration of chitosan and AgNPs. This is due to increasing the quantity of chitosan on fabric surface.

FT-IR of the treated fabrics

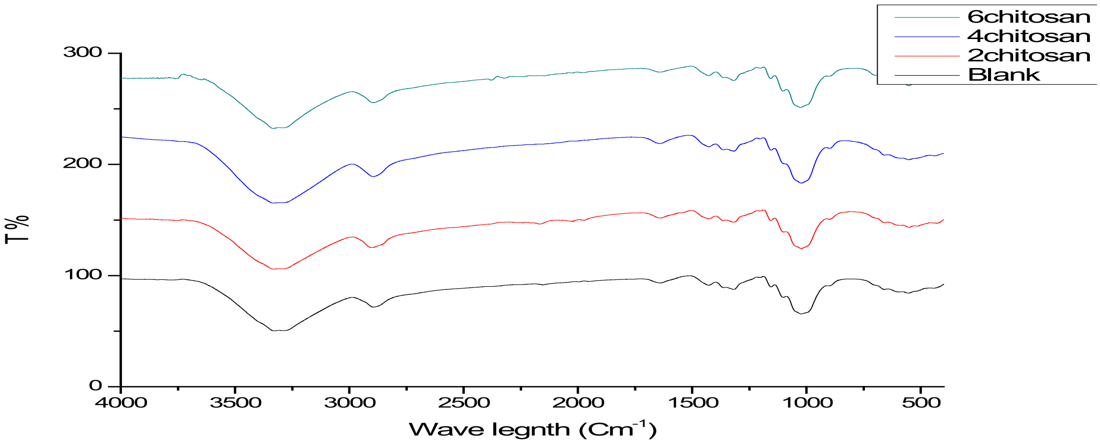
Figure 3 (a, b) show the FT-IR spectra of untreated shibeka fabrics and treated shibeka with different concentrations of chitosan and with different concentrations of AgNP, Figure 3a show peaks at around 3290, 2900, 1580, 1363 and 1057 cm^{-1}, which correspond to the -OH stretching, -CH stretching, -OH of absorbed water from cellulose, -CH2 symmetric bending and -C–O stretching, while it shifted to 3350, 2950, 1620, 1410, 1065 cm^{-1} due to coating the fabrics with chitosan, On the other hand, figure 3b shows no significant changes for fabrics peaks when the fabrics coated with silver nano-particles.

Scanning Electron Microscope (SEM) Analysis

Five micrographs show scanning electron microscope pictures of untreated and treated shibeka samples. Figure 4 shows, for example, homogenous deposition of AgNPs during treatment on cellulosic samples after treatment

TABLE 4. Effect of concentration of treatment materials on some physical and mechanical properties of treated cotton fabrics with different structures.

Construction type	[Chitosan] (%) w/v	[AgNPs] (ppm)	Water permeability (Sec.)	Air permeability ($cm^3/cm^2.sec$)	T.S (Kg)	Elongation at brake (%)
Honycomb	0	-	1.5	66	64	14.1
	2	-	24	64	64	14.5
	4	-	30	63	64.5	14.7
	6	-	36	61	65	14.9
Crepe	0	-	1.7	36	72	19
	2	-	25	35	72.5	19.4
	4	-	31	34	73	19.6
	6	-	37	33	73.5	20
Shibeka	0	-	2	48	65	15.1
	2	-	27	46	65.5	15.3
	4	-	32	45	66	15.7
	6	-	38	44	66.5	16
Honycomb	-	0	1.5	66	64	14.1
	-	100	2	65	64	14.1
	-	200	2.5	56	64.1	14.2
	-	300	2.5	64	64.3	14.3
Crepe	-	0	1.7	36	72	19
	-	100	2.5	35	72.2	19.2
	-	200	2.5	34	72.2	19.2
	-	300	3	34	72.5	19.3
Shibeka	-	0	2	48	65	15.1
	-	100	2.5	47	65	15
	-	200	3	46.5	65.2	15
	-	300	3	46	65.4	15.1



Fig(3a). FT-IR of the treated Shibeka fabrics treated with different chitosan concentration.

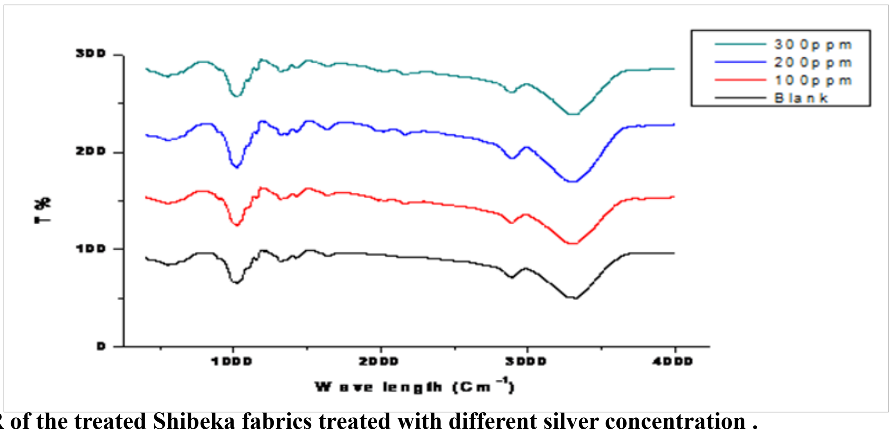


Fig (3b). FT-IR of the treated Shibeka fabrics treated with different silver concentration .

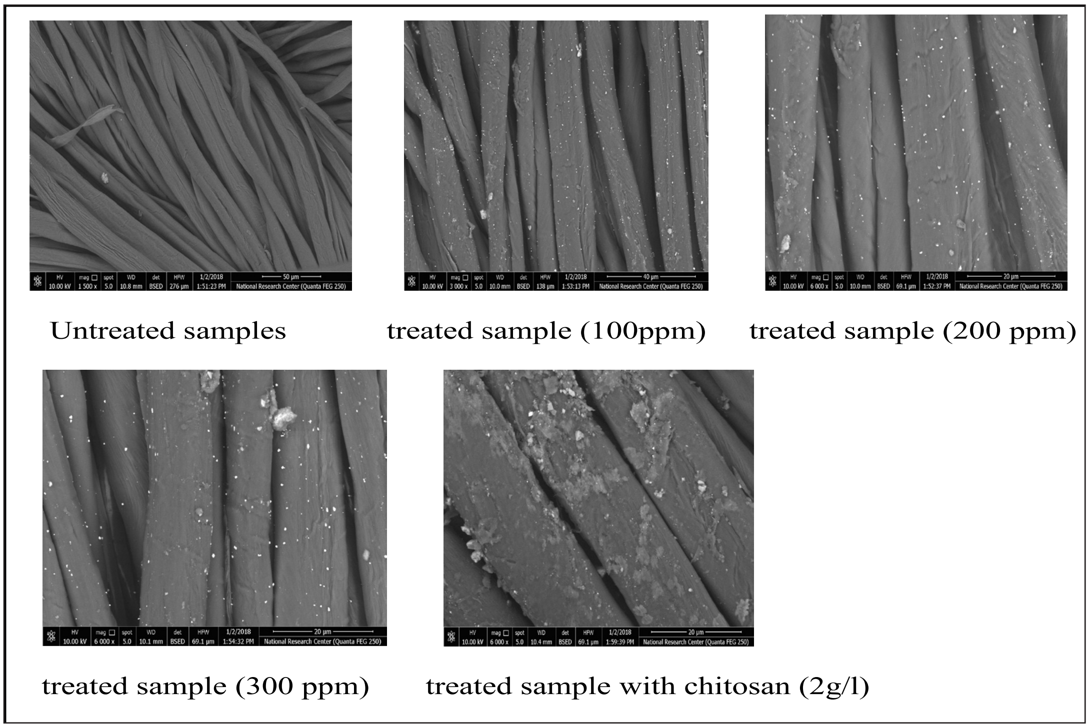


Fig.4. SEM images of the treated Shibeka fabrics with different AgNPs concentration and chitosan (2g/1).

with different concentrations of silver nanoparticles and chitosan.

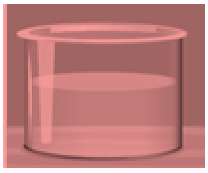
Conclusion

In this paper, we studied the factors affected on some physical and mechanical properties of cellulosic fabrics under investigation, such as microbial resistance, UPF , contact angle , air permeability, water permeability, tensile strength and elongation, were treatment materials (Chitosan and AgNPs) type and concentration and textile construction type. The results show that chitosan concentration has significant effect on the fabrics properties. AgNPs concentration has the same effect on antimicrobial property. So these fabrics can be used for workers in medical purposes and traffic men.

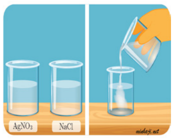
Graphical abstract

Polysaccharide-based textiles

(Cotton fabrics type 1, 2&3)



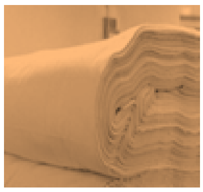
Chitosan



AgNPs + Ethylene glycol

Material with chitosan

was tested for



Material with AgNPs

Antibacterial activity, contact angle, air permeability, water permeability, SEM, FTIR, UPF, T.S and elongation at break. For example

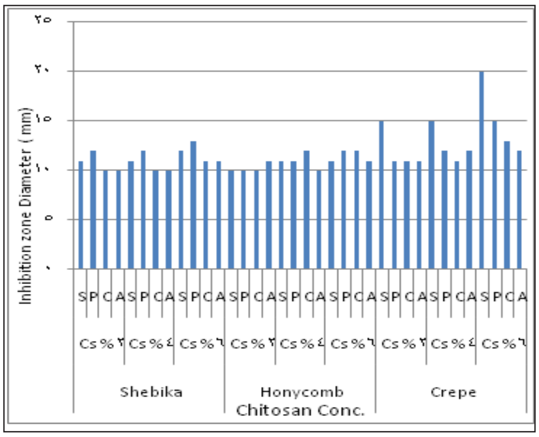


Fig. 1. Antibacterial properties of fabrics treated with chitosan.

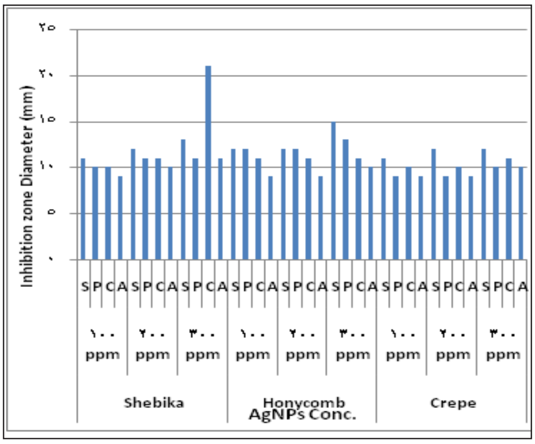


Fig. 2. Antibacterial properties of fabrics treated with AgNPs

NB: Inhibition zone diameter of untreated fabrics = zero mm
Pseudomonas aerugenosa (P), Staphylococcus aureus (S), Aspergillus niger (A) and Candida albicans (C)

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تجهيز منسوجات معتمده على مواد كربوهيدراتيه ضد نمو الميكروبات وللحمايه من الاشعه فوق البنفسجيه باستخدام بوليمرات حيويه وجسيمات الفضه النانومتريه

محمد عبد المنعم رمضان[١]، غادة محمد طه ابراهيم[١]، ولاء زين العابدين المهر[٢]
[١]قسم التحضيرات والتجهيزات للالياف السليلوزية - شعبة بحوث الصناعات النسجيه- المركز القومى للبحوث
[٢] قسم الاقتصاد المنزلي (شعبة النسيج والملابس) - كلية التعليم الخاص -جامعة طنطا

تركزت هذه المقالة على تحضير الأقمشة السليلوزية المضادة للميكروبات والحماية بواسطة بعض البوليمرات الحيوي مثل الكيتوزان و ايضا باستخدام جسيمات الفضة النانومترية،تم استخدام الأقمشة القطنية بثلاثة تركيبات نسجية مختلفة وقد تم اجراء بعض التحاليل للعينات المعالجة بواسطة upf ، SEM، FTIR، antibacterial analysis . ,physical analysis و أوضحت النتائج أن الأقمشة المعالجة بالكيتوزان أعطت أفضل نتيجة لمقاومة الميكروبات و UPF ، مما أدى إلى تقليل نفاذية الهواء وامتصاص الماء بغض النظر عن نوع بناء النسيج المعالج. مما سبق ، يمكن استخدام هذه الأقمشة في أغراض مختلفة مثل المجال الطبي وأقمشة الحماية من الأشعة فوق البنفسجية.