CHITOSAN ADDED COMPOSITE VISCOSE YARN AND ITS POTENTIAL APPLICATION FOR DENIM FABRIC DEVELOPMENT

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ABSTRACT

The rapid increase in consumption has led to the decrease and even extinction of natural resources on earth. The textile industry also has an important place in terms of consumption. The transition to more sustainable biodegradable products instead of established fossil-based materials has increased rapidly due to textile manufacturers and related industries, legal regulations, social responsibility commitments and increasing ecological awareness of customers. Developing new environmentally friendly, biodegradable material groups with new technologies or by modifying existing technologies has been the main goal of many researchers. In this context, we aimed to develop denim fabric that is effective against strong hospital bacteria by using the yarn containing biopolymer chitosan as a weft in denim production.
Chitosan finds wide application in the textile industry due to its biodegradability, antibacterial activity and many more functionalities. Chitosan is used in biomedical textile applications in the textile industry, either as a wound healing, hemostatic (blood stopper), antibacterial, antifungal, either alone or modified to various derivatives or combined with other materials. In this context, instead of using chitosan as a coating material in our studies, chitosan-containing yarn was used in the production of denim fabric in order to distribute the chitosan more homogeneously and to increase the washing resistance. As a result, it was determined that the denim fabric developed by using chitosan-based yarn in weft in denim production reduces hospital bacteria (MRSA-Methicillin resistant staphylococcus aureus) by > 99%.

KEYWORDS

Chitosan; Antibacterial; Denim fabric; Biodegradability; MRSA; Medical textiles.

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INTRODUCTION

Seafood producing companies around the world throw large quantities of crab and shrimp shells into the environment without reuse. In recent years, intensive studies of researchers about the reuse of wastes has also included shrimp and crab shells, and these wastes are evaluated by chemical or biological methods and new products are obtained. Chitin and its most important derivative, chitosan, are among the products obtained in this way. The wastes of the shrimps, whose meat is separated in the processing plants, constitute approximately 40-56% of the total product. Shell wastes also contain very valuable bioactive components such as antioxidants, peptones, amino acids, peptides, proteins, minerals, enzymes, lipids and other beneficial nutrients. The raw material requirement for the production of chitin is met from shrimp (56,000 tons), various shellfish (39,000 tons), mushrooms (32000 tons), oysters (23000 tons). In Figure 1, the production process of the chitin is shown.

Chitosan is a biopolymer obtained by deacetylation of chitin (β-(1-4)-poly-N-acetyl-D-glucosamine), which is the most common in nature after cellulose. In Figure 2, the production process of the chitin with the chemical method is shown.

Chitosan, a natural biopolymer with biocompatible, non-toxic and antibacterial properties, can be used in different forms such as solution, powder, fiber and film [12]. The reason for the analgesic effect of chitosan is due to its polycationic structure. The biodegradability of chitosan is due to the fact that chitosan is not only a polymer carrying amino groups, but also a polysaccharide, which as a result contains brittle glycosidic bonds. [7].

Figure 1. Production process of chitin [5].

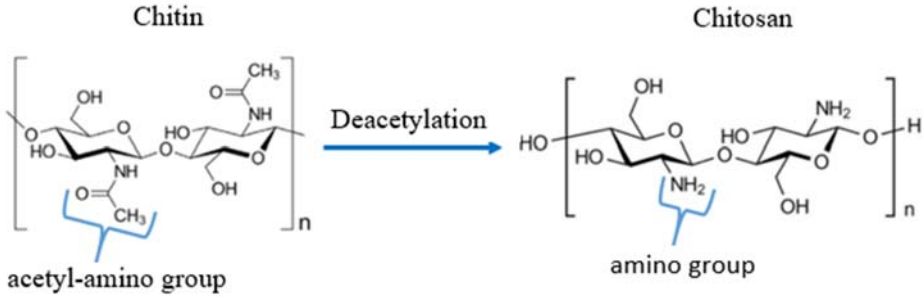

Figure 2. Chitosan from chitin via deacetylation [5].

The presence of amino groups in the chitosan structure (Figure 3) distinguishes it from chitosan, and this difference gives the polymer many special properties. The amino groups in the chitosan structure can be protonated by providing solubility in diluted acidic aqueous solutions. In contrast, the practical applications of chitin, if any, are extremely limited due to its poor solubility [2].

In addition, due to these amino groups, chitosan efficiently complexes various species such as metal ions and is therefore often used in wastewater treatment, purification by recovery of heavy metals (Rinaudo 2006).The hemostatic property of chitosan can also be associated with the presence of positive charges present in chitosan. This is because the membranes of red blood cells are negatively charged and therefore can interact with the positively charged chitosan. The fact that chitin has less hemostatic properties than chitosan tends to confirm this explanation [2].

Chitosan can be converted into many forms such as hydrogel, sponge, membrane, film, depending on the area of use. As it is known, sponges are open-pore foams and can absorb large amounts of liquid due to their microporosity. Chitosan-based sponges are mostly used as wound-healing materials, as they can absorb wound exudates while aiding tissue regeneration. Chitosan sponges also find application in bone tissue engineering as filling material [9, 8].

Stegmaier et al. investigated the use of chitosan as a sizing agent with appropriate modification in the textile industry. As a result of these studies, economic and ecological advantages in sizing have been demonstrated by increasing the weaving efficiency based on the reduction of yarn breaks with chitosan-based sizing [11].

The use of chitosan as an absorbent in the removal of dyes to treat textile wastes has been investigated. In this context, chitosan was found to be very effective in removing dianix orange S-G, a disperse dye, from wastewater. Dye removal was carried out using the ability of chitosan to dissolve in acidic medium and reform in basic medium [14].

Chitosan has been used as an aid to increase the uptake of anionic dyes in textile dyeing. Chitosan is used instead of salt in reactive dye dyeing of cotton fabric. Cellulosic fiber takes a negative charge in the aqueous medium and repels the negatively charged dye anion during dyeing. Such repulsion between fiber and dye is avoided by using salt in the dyebath for reactive dyes.

By treating cotton fabric with chitosan, Ashenafi et al. revealed that surface modification of cotton provides better dyeing properties and the best possibility for salt-free dyeing of cotton may be the use of chitosan [1].

Erdoğan et al. aimed to develop a new generation of environmentally friendly antibacterial finishes by using chitosan as a binder for nano-silver coatings. In the study, chitosan formed a colorless film and formed a matrix that allowed nano-Ag particles to accumulate homogeneously on the fabric surface, and as a result, a very strong anti-nacterial effect was observed [4].

Chitosan can be crosslinked with cellulose using polycarboxylic acids, thus providing better bonding between chitosan and cotton fabric. A good wrinkle recovery was obtained in cotton as a result of the cross-linking of chitosan and cellulose by polycarboxylic acids [13].

Ivanova et al. developed super hydrophobic and anti-bacterial textiles using chitosan-based nanoparticles for biomedical applications (6). In their studies, Raeisi obtained superhydrophobic cotton fabrics by using chitosan and titanium dioxide (TiO_2) nanocomposites [10].

MRSA (also known as supervirus) stands for methicillin-resistant Staphylococcus. MRSA is a "staph" germ (bacteria) that does not get better with

the type of antibiotics that usually cure staph infections. These kind of staph germs are spread by skin-to-skin contact. Healthcare personnels or visitors to a hospital may carry staph germs on their body which can spread to a patient. After entering to the body through open wounds, burns or cuts can this staph germ spread to bones, joints, the blood, or any organ, such as the lungs, heart, or brain and can cause serious health problems. If we list the groups at risk in addition to healthcare personnel: athletes who share items such as towels or razors, draggie, people who had surgery in the past year, children in day care, members of the military.

Denim is a textile product that can be worn by people of all ages and kinds. From this point of view we aimed to developped a denim fabric, which controbute to reduction of super virus MRSA spreading among both healthcare personnel, hospital visitors and above mentioned people at risk. In line with this purpose we used chitosan containing weft yarn in denim.

EXPERIMENTAL

Materials

The application of chitosan to cotton fabrics has mostly been in the form of microcapsules of powdered chitosan or in the form of coating by dissolving in acid. In order to make chitosan more homogeneous and permanent in denim fabric, chitosan-based yarn was supplied in this study. For the denim production was used Ne 30/1 chitosan-based yarn as weft.

The physical properties of chitosan containing yarn as weft in denim production are shown in Table 1. When yarns are compared especially in terms of hardness and elongation, it is seen that chitosan-based yarn is better.

Methods

The developed denim with chitosan rayon yarn and cotton yarn in weft is weaved according to procedure in Table 2. The processes applied to the weaved denim fabrics are summarized in Figure 3.

Table 1. The physical properties of in denim production used yarn.

Yarn	Ne	%U	Hairness	Elongation	Stiffness
Chitosan viscose yarn	30/1	10,1	4,73	9,21	17,96
Combed cotton yarn	30/1	10,5	5	5,5	15,5-16

Table 2. Weaving procedure.

	Warp Yarn	Warp Yarn Number Ne	Weft Yarn	Weft Yarn Number Ne	Weft density	Weaving Type	Warp Wire Count	Comb Width	Comb No/Number of wire through
Sample 2	%100 CO	20/1	%100 CO	30/1	27,5	3/1 Z	5880	210	140/2
Sample 1	%100 CO	20/1	Chitosan based	30/1	27,5	3/1 Z	5096	182	70/4

Figure 3. Applied processes to the weaved denim fabric.

RESULTS AND DISCUSSION

FT-IR Analysis of chitosan containing yarn

The FT-IR spectra for commercial chitosan powder in comparison with chitosan rayon yarn, which is used as weft in denim is illustrated in Fig. 4. The main characteristic peaks of commercial chitosan powder are at 3357 (–OH & -NH stretch), 2974 (C–H stretch), 1647 and (N–H bend), 1374 (bridge O stretch), and 1024 cm^{-1}(C–O stretch). Whereas the main corresponding peaks of chitosan rayon yarn were at 3350, 2880, 1652, 1378 and 1024 cm^{-1} respectively.

SEM/analysis

To compare the structure of the chitosan containing rayon yarn with cotton yarn cross-section of fibers were studied using SEM. When the cross-section images of chitosan containing yarn are compared with commercial viscose rayon fiber product, the similarity can be seen in figure 6. The both fibre have close to circular cross-section.

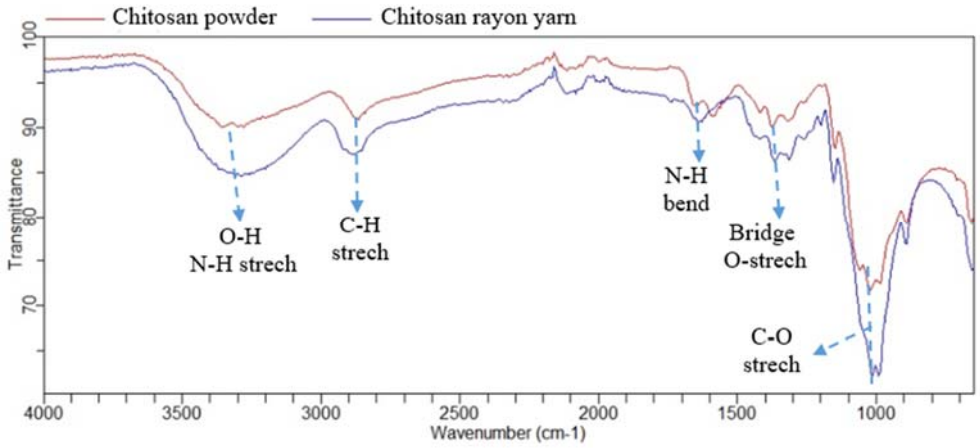

Figure 4. FT-IR spectra of commercial chitosan powder and chitosan viscose yarn.

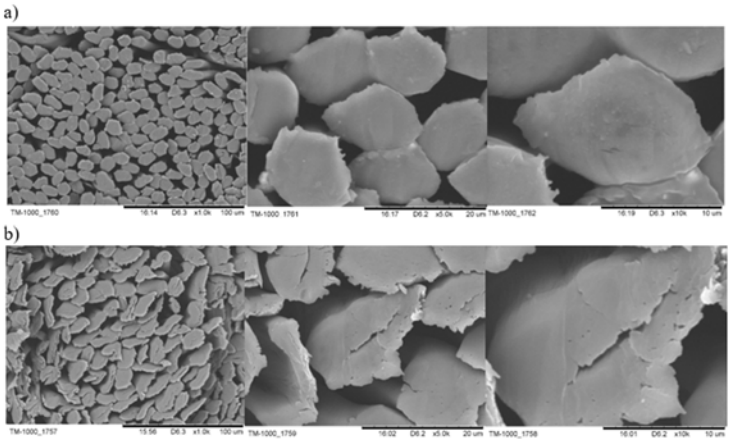

Figure 5. SEM Pictures of: (a) Cross section of chitosan containing rayon yarn Ne 30/1 (1000/5000/10000), (b) Cross section of cotton yarn Ne 30/1, (1000/5000/10000).

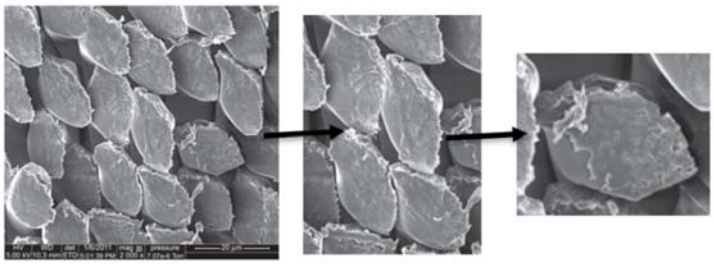

Figure 6. Lyocell rayon fiber cross-sectional view SEM [3].

Physical Properties of Weaved Denim

The weaved two denim fabrics with the same warp and different weft were compared relates to their physical properties. Dry-wash crocking results of both fabrics seems to be practically same. According to tear result of chitosan containing yarn compared with Ne 30/1 cotton yarn in weft is more durable than cotton yarn (Table 3).

Determination of antibacterial activity: The antibacterial activity of developped denim with chitosan containing yarn in weft was determined acoording to AATCC 100:2019 standards with the test organism staphylococcus aureus MRSA (ATCC 33591) in Intertek Testing Services Taiwan Ltd. As can be seen from the result in Table 3, the super bacteria MRSA is reduced by more than 99.92 % on the developed denim fabric.

After 24 hours of incubation the reduction in methicillin staphylococcus aureus MRSA (ATCC 33591) is depicted in Figure 7.

The positively charged ions provided by Chitosan concentrate on the surface of the fabric and provide antibacterial protection to the fabric. When bacteria containing negative ions come into contact with the chitosan surface on the fabric; The positively charged ions bind to the bacteria and cause their enzymes to break down. The enzymes are then unable to produce energy, which inhibits the bacteria from multiplying and the bacteria eventually die.

Table 3: Physical Properties of weaved denim.

Weft Yarn	WEIGTH		WEIGTH		CROCKING		STIFFNESS	pH	TENSİLE (kgf)		TEAR (grf)	
	DRY gr/m²	WASH gr/m²	DRY oz/yd²	WASH oz/Yd²	DRY	WET			WARP	WEFT	WARP	WEFT
Ne 30/1 Chitosan containing	176	177	5,2	5,2	2-3	1-2	0,28	4,54	43	24	3588	2936
Ne 30/1 Cotton	189	173	5,6	5,1	3	1-2	0,25	4,87	40	26	3719	2675

Table 4. Antibacterial activity test result of developed denim fabric.

Name Of Test Bacteria (Strain Number)	*Methicillin resistant staphylococcus aureus* (ATCC 33591)
The number of bacteria recovered from the inoculated viability control fabric swatches immediately after inoculation ("0" contact time) (D)	1.5 X10^5 CFU/Sample
The number of bacteria recovered from the inoculated viability control fabric swatches incubated over 24 hours contact period (B)	1.8 X10^7 CFU/Sample
The number of bacteria recovered from the inoculated tested sample swatches immediately after inoculation ("0" contact time) (C)	1.3 X10^5 CFU/Sample
The number of bacteria recovered from the inoculated tested sample swatches incubated over 24 hours contact period (A)	<100 CFU/Sample
Growth value (F)	2.08
Percent reduction of Bacteria (R)	>99.92%

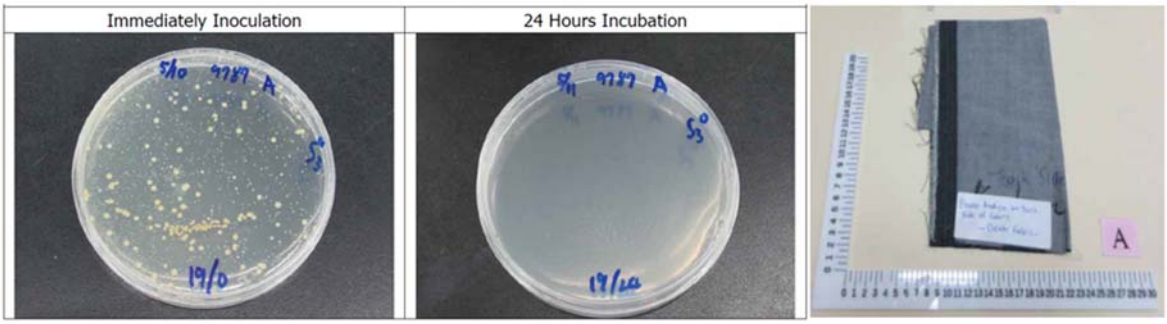

Figure 7. Reduction of MRSA after 24 hours incubation.

CONCLUSIONS

Chitosan is a biopolymer with biocompatible, non-toxic and antibacterial properties which is the most common in nature after cellulose. In this work, it is aimed to create a denim fabric containing chitosan rayon yarn. For this purpose, we provided with wet spinning method produced chitosan containing yarn in order to use as weft yarn in denim. The antibacterial activity of developped denim with chitosan containing yarn in weft was determined acoording to AATCC 100:2019 standards with the test organism staphylococcus aureus MRSA (ATCC 33591) in Intertek Testing Services Taiwan Ltd. The super bacteria MRSA is reduced by more than 99.92 % on the developed denim fabric. As far as we know, it exists any study in the literature related to the use of chitosan as weft yarn in denim related to activity gains methicillin staphylococcus aureus MRSA (ATCC 33591).

Denim is a textile product that can be worn by people of all ages and kinds. From this point of view we succeed to developped a denim fabric, which controbute to reduction of super virus MRSA spreading among both healthcare personnel, hospital visitors and soldiers, athletes at risk. If this product is used by healthcare personnel or hospital visitors can protect their health and reduce the casualties of patients caused by MRSA nosocomial infections, and reduce huge medical expenses.

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REFERENCES

1. Bethlehem, A., Studies on dyeing properties of chitosan modified cellulosic fiber, Journal of Textile Engineering & Fashion Technology. 2020;6(1):37–42. http://dx.doi.org/10.15406/jteft.2020.06.00224
2. Croisier, F., 2013, Chitosan-based biomaterials for tissue engineering European Polymer Journal 49 (2013) 780–792 http://dx.doi.org/10.1016/j.eurpolymj.2012.12.009
3. Chen, J., 2015. Synthetic textile fibers: regenerated cellulose fibers. In: Sinclair, R. (Ed.), Textiles and Fashion. Woodhead Publishing in Association with the Textile Institute. http://dx.doi.org/10.1016/B978-1-84569-931-4.00004-0
4. Erdoğan, S., Textilefinishing with chitosan and silver nanoparticles against Escherichia coli ATCC 8739, Trakya University Journal of Natural Sciences, 21(1): 21-32, 2020 ISSN 2147-0294, e-ISSN 2528-9691 https://doi.org/10.23902/trkjnat.641367
5. Kuzgun N., Chitosan Production, Chitosan Properties and Usage Areas., Türk Bilimsel Derlemeler Dergisi 6 (2): 16-21, 2013
6. Ivanova, N.A., Superhydrophobic chitosan-based coatings for textile processing, Applied Surface Science 263 (2012) 783–787 https://doi.org/10.1016/j.apsusc.2012.09.173
7. Ibrahim, H. M., 2015, Concepts, Compounds and the Alternatives of Antibacterials, Chitosan as a Biomaterial — Structure, Properties, and Electrospun Nanofibers. 10.5772/59522(Chapter 4) https://dx.doi.org/10.5772/61300
8. Lee Y-M, Park Y-J, Lee S-J, Ku Y, Han S-B, Choi S-M, et al. Tissue engineered bone formation using chitosan/tricalcium phosphate sponges. J Periodontol 2000;71:410–7. https://doi.org/10.1902/jop.2000.71.3.410
9. Costa-Pinto AR, Reis RL, Neves NM. Scaffolds based bone tissue engineering: the role of chitosan. Tissue Eng Part B, 2011;17:331–47. https://doi.org/10.1089/ten.teb.2010.0704
10. Raeisi, M., Superhydrophobic cotton fabrics coated by chitosan and titanium dioxide nanoparticles with enhanced antibacterial and UV-protecting properties International Journal of Biological Macromolecules 171 (2021) 158–165 https://doi.org/10.1016/j.ijbiomac.2020.12.220
11. Stegmaier, T., Chitosan – A Sizing Agent in Fabric Production – Development and Ecological Evaluation, Clean 2008, 36 (3), 279 – 286 http://dx.doi.org/10.1002/clen.200700013
12. Şahan, G., 2014, Kitosan biyopolimerinin formları ve tekstil uygulamaları, XIII. Uluslararası İzmir Tekstil ve Hazır Giyim Sempozyumu,170
13. Sunder, Edwin A., 2014, Croslinking of Chitosan with Cotton using Polycarboxylic Acids, International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, Vol 3 Issue 4,
14. Vithanage, A.H., 2015, Textile Dye Removal in Wastewater Using Chitosan, Annual Sessions of IESL, pp. [1 - 10], doi:10.4028/www. scientific.net /AMR.610-613.3394