Investigation of radiation shielding, antibacterial and some properties of nanosilver applied and coated woven fabrics

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ABSTRACT – REZUMAT

Investigation of radiation shielding, antibacterial and some properties of nanosilver applied and coated woven fabrics

Antibacterial textiles are widely used in terms of providing hygiene and comfort by protecting human health. Due to its importance in the health sector and increasing customer demands, the trend towards these textiles is increasing day by day. In this study, the antibacterial properties of cotton and cotton/polyester woven fabrics which had applied impregnation and coating processes were examined and compared. For this purpose, nano silver-containing chemicals were applied to the fabrics by impregnation method to give antibacterial properties. After this, the fabrics were coated with tungsten and barium sulphate which have different properties, and coating fabric with antibacterial and radiation shielding properties is obtained. To examine some properties of these antibacterial fabrics, tensile strength, washing fastness, friction fastness tests and SEM analysis were applied to the fabrics. The coating and impregnated fabrics were compared with the fabrics that had been coated only.

Keywords: *antibacterial property, nano silver, coating, radiation shielding, woven fabric*

Investigarea proprietăților de protecție împotriva radiațiilor, antibacteriene și altor proprietăți ale țesăturilor impregnate și peliculizate cu nanoargint

Textilele antibacteriene sunt utilizate pe scară largă pentru asigurarea igienei și confortului prin protejarea sănătății umane. Datorită importanței lor în sectorul sănătății și a cerințelor în continuă creștere ale clienților, tendința către utilizarea acestor materiale textile crește pe zi ce trece. În acest studiu, au fost analizate și comparate proprietățile antibacteriene ale țesăturilor din bumbac și bumbac/poliester pentru care a fost aplicat un proces de impregnare și peliculizate. În acest scop, substanțe chimice care conțin nanoargint au fost aplicate pe țesături prin metoda de impregnare, pentru a conferi proprietăți antibacteriene. După aceasta, țesăturile au fost peliculizate cu tungsten și sulfat de bariu care au proprietăți diferite și se obțin astfel, țesături peliculizate cu proprietăți antibacteriene și cu rezistență împotriva radiațiilor. Pentru a analiza alte proprietăți ale acestor țesături antibacteriene, au fost realizate teste de rezistență la tracțiune, rezistență la spălare, de rezistență la frecare și analiza SEM. Pelicula și țesăturile impregnate au fost comparate cu țesăturile care au fost doar peliculizate.

Cuvinte-cheie: *proprietate antibacteriană, nanoargint, peliculizare, protecție împotriva radiațiilor, țesătură*

INTRODUCTION

Antibacterial products are used to eliminate or minimize the effect of microorganisms that harm the textile product and the user [1]. Antibacterial textiles are used as medical garments, surgical applications, sportswear, socks, military uniforms, underwear, tents, curtains, bath covers, outdoor garments, filter making, the construction of various technical fibres, the automotive industry, food industry in many areas [2]. In antibacterial finishing processes, the methods of extraction, impregnation, vacuum application, maximum liquor application, transfer, spraying, foam application and coating are used. Impregnation, coating and spraying methods are the most commonly used methods [3]. Alcohols, metals, phenols and derivatives, halogens, oxidation agents, biquanidines, isothiazolones, ammonium compounds, zeolites, chitin and chitosan are the most important antibacterial agents [4].

To improve the functionality and performance characteristics of woven, knitted and non-woven fabrics, one or two surfaces are applied chemical substances to obtain coating fabric [5, 6]. Properties that are not present on the textile surface are imparted to the textile surface by the coating process [6]. In recent years, with the increasing trend towards technical textiles, the trend towards coating fabrics has also increased [7].

In this study, nano-silver, which is one of the most important antibacterial materials in giving antibacterial properties, had been applied to woven fabrics by impregnation method which is one of the most widely used methods and then was coated with tungsten and barium sulfate, blade coating. Thus, it was aimed to give antibacterial and radiation shielding properties to woven fabrics that had been impregnated and coated. In addition, coated fabrics which weren't applied nanosilver and coated fabrics which were applied nanosilver were compared with each other.

MATERIALS AND METHODS

Material

Cotton fabrics; easily absorbs fluids such as blood and urine from the body due to their liquid-absorbing properties. It has the property of taking liquid and passing gas and water vapour. It has a heat-resistant, insulating, non-allergic soft tissue and is frequently preferred in daily life. Cotton/polyester fabrics are widely used in daily use due to their high strength, and advantages in ironing and are frequently preferred in surgical garments [8, 9]. Because of these properties of cotton and cotton/polyester, cotton (97% cotton, 3% elastane) and cotton/polyester (59% cotton, 39% polyester, 2% elastane) woven fabrics were used in this study. The properties of these fabrics are shown in table 1.

Table 1

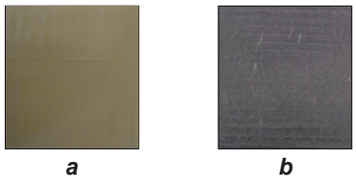
FEATURES OF COTTON FABRIC				
Cotton fabric	**Density (wire/cm)**	**Yarn number (Ne)**	**Fiber type**	**Weight (g/m²)**
Weft	55	20	Cotton/ Lycra	247
Warp 1	33	12	Cotton	
Warp 2	33	12		
FEATURES OF COTTON/POLYESTER FABRIC				
Weft 1	34	28	PES/ Lycra	236
Weft 2	34	18		
Warp	60	20	Cotton	

In this study, a 20–25 nm size nanosilver which was provided by NANOKAR® Nano Technological Materials was used to give antibacterial properties to woven fabrics. Nanosilver particles pass
through the cell membrane of bacteria and microbes, disrupt DNA and prevent the reproduction of bacteria and microbes [10]. Silver is effective against more than 650 microorganisms that cause diseases [11]. Silver, bacteria and germs with resistance to the product provide a deodorizing property, as well as the use of a certain amount of silver does not harm the human body [12]. It is used in socks, underwear, sheets, armchair upholstery, the military and the medical field in the textile field [13]. Although metal ions such as copper, zinc, gold and titanium have antimicrobial effects, silver shows the best antimicrobial properties. At present, silver-containing products are used in the treatment of burns, wounds, and bacterial infections. In addition, silver-containing wound dressings are used for antibiotic-resistant bacteria [14].
In this study, *Staphylococcus aureus* (ATCC 6538), a common bacterium in hospitals that is the cause of many infections and *Escherichia coli* (ATCC 35218) in the hands and toes, soles, scalp, armpits, palms and stools in contact with textile surfaces were used to test antibacterial properties of the fabrics [15, 16].

It was aimed to compare the effect of nanosilver applied to woven fabrics by impregnation method on the antibacterial properties of the fabrics by coating them with barium sulfate and tungsten having two different properties. In addition, in future studies, it is thought that functional textile products can be obtained by using the properties of barium sulfate and tungsten. Tubicoat CRO was used as a coating chemical and was provided by CHT Kimya A.Ş. The barium sulphate was provided by Emir Kimya and the tungsten was provided by Baymet Foreign Trade Limited Company. Barium sulfate is a cheap mineral, it has a resistant structure. It is used in sports equipment, coating of carpets and similar products, the pharmaceutical sector due to its toxin cleansing properties, the paint sector due to its whitening and thinning properties, drilling works, nuclear power plants, hospitals, X-ray works, in many processes such as paper production [17, 18]. Tungsten is a metal that has more hardness than many sheets of steel, can be easily processed, has good abrasion resistance and thermal conductivity, has a high melting and boiling point, and is resistant to acids and alkalis for a long time. It is used in the arms and defence industry, space technology, ships, airplanes, automotive, bulb wires, X-ray devices, anti-radiation screens, television tubes, and jewellery as an alternative to platinum and gold [19].

Methods

In this study, after the nanosilver impregnation method was applied to cotton and cotton/polyester woven fabrics, the fabrics were coated with tungsten and barium sulfate. The fabrics which were applied impregnation and coating process and the fabrics that applied only the coating process were tested for antibacterial properties with AATCC 100 method.
1% nano silver and pure water were applied to cotton and cotton/polyester fabrics at Ataç brand FY 350 fulars under two bar atmospheric pressure [20, 21].
The impregnated fabrics were dried at 80°C for 15 minutes and fixed for 3 minutes at 100°C in Mathis fixing machine.
The homogeneous mixture was obtained by using 60% Tubicoat CRO as the coating chemical and 40% barium sulphate and tungsten were coated with the help of a stripper on the fabrics which were applied nanosilver. In figure 1, barium sulfate (*a*) and tungsten (*b*) coated fabrics are shown. After coating, the barium sulfate-coated fabric was dried for 15 minutes at 80°C, the tungsten-coated fabric was dried for 10 minutes at 80°C and the fixation process was carried out for 3 minutes at 100°C.



a ***b***

Fig. 1. Fabrics coated with:
a – barium sulfate; *b* – tungsten

AATCC 100 antibacterial test method was used to quantitatively investigate the antibacterial properties of woven fabrics that were impregnated and coated. To determine the effect of impregnation and coating methods applied to woven fabrics on the tensile strength of fabrics, the tensile strength test of Llyod brand LR5K model strength tester according to TS EN ISO 13934-1 standard, SEM analysis on Quanta FEG 250 SEM device to determine the change in fabric structure, to determine the effect of washing process on fabrics, washing fastness test in ISO 105-C06 standard and to determine the effect of friction on fabrics, friction fastness test according to TS EN ISO 105-X12 standard was applied.
In this study, the neutron absorption properties of coated woven fabric samples were experimentally measured. Neutron measurement was made by a removable He-3 proportional detector. The fabrics used in the study and the applications made are shown in table 2.

Table 2

Fabrics	Application
1	Untreated Cotton
2	Cotton-Nano Silver
3	Cotton-Barium Sulfate
4	Cotton-Nano Silver-Barium Sulfate
5	Cotton-Tungsten
6	Cotton-Nano Silver-Tungsten
7	Untreated Cotton/Polyester
8	Cotton/Polyester -Nano Silver
9	Cotton/Polyester-Barium Sulfate
10	Cotton/Polyester-Nano Silver-Barium Sulfate
11	Cotton/Polyester-Tungsten
12	Cotton/Polyester-Nano Silver-Tungsten

FINDINGS

Antibacterial test

According to AATCC 100 antibacterial test method cotton and cotton/polyester woven fabrics' antibacterial activity, values are given in table 3 against *S.aureus* and antibacterial activity values are given in table 4 against *E.coli.*
In AATCC 100 Antibacterial test method, (–) values indicate a decrease in the number of bacteria, and (–) 100 indicates that all bacteria are dead.
When the antibacterial properties of the samples against *S.aureus* bacteria were examined, it was seen that all bacteria killed in cotton and cotton/polyester samples coated with barium sulphate and nanosilver and other coating samples had antibacterial properties. The antibacterial properties of barium sulfate-coated samples were found to be slightly better than tungsten-coated samples.
When the antibacterial properties of the samples against *E.coli* bacteria were examined, it was determined that all bacteria were killed in the nanosilver-coated samples. Bacterial growth was observed on

Table 3

ANTIBACTERIAL ACTIVITY OF SAMPLES AGAINST *S.aureus*	
Fabrics	**Bacteria reduction (%)**
1	–56.08
2	–100
3	–99.96
4	–100
5	–99.43
6	–99.35
9	–99.78
10	–100
11	–99.46
12	–99.57

Table 4

ANTIBACTERIAL ACTIVITY OF SAMPLES AGAINST *E.coli*	
Fabrics	**Bacteria reduction (%)**
1	7.22
2	–99.98
3	118.18
4	–100
5	130.30
6	–99.58
9	143.64
10	–100
11	180
12	–99.70

cotton and cotton/polyester fabrics coated with tungsten and barium sulfate.
Tungsten-coated nano silver applied samples were found to have antibacterial properties. Antibacterial properties of barium sulfate-coated samples were detected to be slightly better than tungsten-coated samples.

Tensile strength

Tensile strength and elongation at break values of the samples are given in table 5.
When table 5 is examined, it has been determined that barium sulfate-coated fabrics have better breaking strength values than tungsten-coated fabrics, cotton fabrics coated with barium sulphate have lower breaking elongation values than tungsten-coated fabrics, and in other samples barium sulfate-coated fabrics have higher breaking elongation than tungsten-coated fabrics.

Washing fastness

The washing fastness values of the samples are given in table 6.
When table 6 is examined, it has been determined that coating and impregnation processes do not have

Table 5

TENSILE STRENGTH AND ELONGATION VALUES OF SAMPLES				
Fabrics	Tensile strength (N)		Elongation at break (%)	
	Warp	Weft	Warp	Weft
1	1077	285	29	75
2	1078	337	28	77
3	1246	315	30	84
4	1200	317	27	82
5	1225	56	35	94
6	1104	57	20	77
9	1936	705	31	84
10	1603	409	27	92
11	1200	150	22	30
12	961	209	20	39

Table 6

WASHING FASTNESS VALUES OF SAMPLES						
Fabrics	Fading					
	Acetate	Cotton	Polyamide	Polyester	Acrylic	Wool
3	5	5	5	5	5	5
4	5	5	5	5	5	5
5	5	5	5	5	5	5
6	5	5	5	5	5	5
9	5	5	5	5	5	5
10	5	5	5	5	5	5
11	5	5	5	5	5	5
12	5	5	5	5	5	5

a negative effect on the fastness of washing of fabrics.

Friction fastness

Friction fastness values of the samples are given in table 7.

Table 7

FRICTION FASTNESS VALUES OF SAMPLES		
Fabrics	Friction fastness	
	Dry	Wet
3	5	4–5
4	5	5
5	5	5
6	5	4–5
9	5	4–5
10	5	5
11	5	4
12	5	4–5

When table 7 is examined, it has seen that coating and impregnation processes have no negative effect on the friction fastness of the fabrics. The dry friction fastness values of the samples are 5 and the wet friction fastnesses are 4, 4-5, 5.

SEM Analysis

Samples were magnified in the range of 500–10.000 and the most suitable samples were selected. SEM analysis images of the samples were indicated in figures 2 and 3.

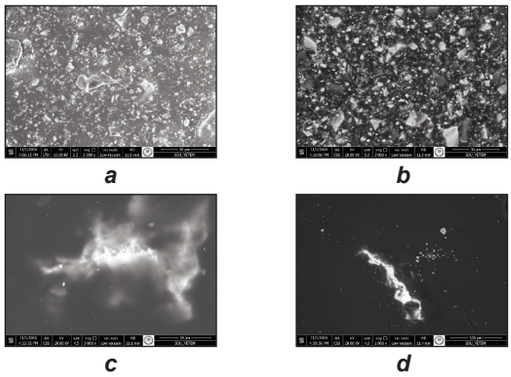


Fig. 2. Cotton fabrics coated with: *a* – barium sulfate; *b* – barium sulfate-nano silver; *c* – tungsten; *d* – tungsten-nano silver

As shown in figure 2, barium sulphate applied cotton fabric (figure 2, *a*) and barium sulfate-nano silver applied cotton fabric (figure 2, *b*) 3000 times, tungsten applied cotton fabric (figure 2, *c*) 5000 times, tungsten-nano silver applied cotton fabric (figure 2, *d*) 1000 SEM image was taken enlarged.

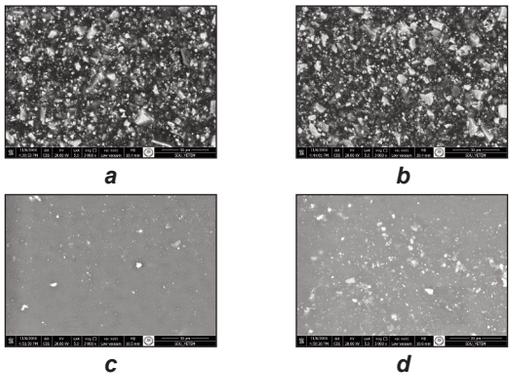


Fig. 3. Cotton/polyester fabrics coated with: *a* – barium sulfate; *b* – barium sulfate-nano silver; *c* – tungsten; *d* – tungsten-nano silver

As shown in figure 3, barium sulphate applied cotton/polyester fabric (figure 3, *a*) and barium sulfate-nano silver applied cotton/polyester fabric (figure 3, *b*) and tungsten applied cotton/polyester fabrics (figure 3, *c*) 3000 times, tungsten-nano silver applied cotton/polyester fabric (figure 3, *d*) 5000 SEM image was taken enlarged.

When figures 2 and 3 were examined, the surface distribution of barium sulfate and tungsten was observed to be different. It was seen that barium sulfate covered the whole surface in cotton and cotton/polyester fabrics and tungsten covered a narrower

area in coated fabrics. The distribution of tungsten on the surface of cotton/polyester fabric was found to be higher than cotton fabric. Because the application rate of nanosilver to the fabric was 1%, it wasn't clearly seen on the fabric surfaces.

Radiation shielding

The neutron measurement of the device is provided by the Helium-3 proportional detector. Measurements were made with a neutron detector at 2.3 MeV neutron energy emitted from a ^{252}Cf neutron source. By using the dose values obtained as a result of the measurements, the linear absorption coefficient of a sample of *x* thickness was calculated with the following formula [22].

$$N(x) = No\ e^{-\mu x} \quad (1)$$

Here, μ is the linear absorption coefficient, *x* – the thickness of the sample, *N*(*x*) – the dose measured when there is a sample of *x* thickness between the detector and the source, and *No* – the dose value measured when there is no sample between the detector and the source. The neutron absorption coefficients of the fabrics were measured. The results obtained are given in figure 4.

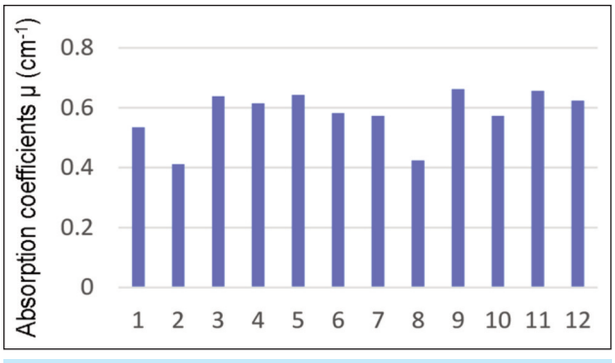


Fig. 4. Neutron absorption coefficients of fabrics

When the neutron absorption coefficient values of the treated fabrics given in figure 4 are examined, the values vary between 0.6616 and 0.4114. The highest value belongs to the barite-coated cotton/polyester fabric, while the lowest value belongs to the Nanosilver-applied cotton/polyester fabric. Tungsten and barite coating increased the neutron absorption coefficient values. Neutron absorption coefficient values of tungsten-applied fabrics are higher than barite-applied fabrics. It has been observed that nano silver application reduces the neutron absorption coefficient values of the fabrics. Neutron absorption coefficient values of cotton/polyester fabric are generally higher than cotton fabric.

CONCLUSION

When the results of antibacterial properties of gram-positive and gram-negative bacteria according to the AATCC 100 antibacterial test method after applying to the woven fabrics by nano silver impregnation method coated with tungsten and barium sulfate and woven fabrics only coated with tungsten and barium sulfate were examined, all coating woven fabrics with nano silver have antibacterial properties. While antibacterial properties were observed against *S. aureus* bacteria in nano silver not applied coated fabrics, antibacterial properties were not observed in nano silver not applied coated fabrics using *E. coli* bacteria. When the non-nano silver coated coating fabrics were considered, *E. coli* bacteria are more resistant than *S. aureus* bacteria was observed. When the antibacterial properties of barium sulfate and tungsten-coated fabrics were compared, it was seen that barium sulfate-coated fabrics had slightly more antibacterial properties than tungsten-coated fabrics. In this study, gamma ray shielding properties of coated woven fabrics were investigated. The advantage to being provided to the fabric in this study is to obtain an antibacterial fabric that can absorb neutron rays. The neutron absorption properties of coated woven fabric samples were experimentally measured. The neutron measurement of the device is provided by the Helium-3 proportional detector. Measurements were made with a neutron detector at 2.3 MeV neutron energy emitted from a 252Cf neutron source. Barium sulfate-coated cotton/polyester fabric has the highest neutron absorption coefficient, while nano silver applied cotton/polyester fabric has the lowest neutron absorption coefficient. Tungsten and barite coating have affected the neutron absorption coefficient values in the direction of increase. Neutron absorption coefficient values of tungsten-coated fabrics are higher than barium sulfate-coated fabrics. Nanosilver application negatively affected the neutron absorption coefficient values of the fabrics.

When the tensile strength of the samples is examined, it is observed that barium sulfate-coated fabrics are more durable than tungsten-coated fabrics. It was determined that barium sulfate used fabrics for nanosilver-applied antibacterial fabrics would be more suitable in terms of durability. When washing fastness and friction fastness tests were examined, it was seen that there was no negative situation in the washing and friction fastness of the fabrics with the coating process and these fabrics were resistant to washing and friction. When SEM images of the samples were examined, it was observed that barium sulfate spread is more than tungsten on the sample. In terms of antibacterial properties of nanosilver applied to the fabric were not very clear on the surface.

In addition to these properties of cotton and cotton/polyester fabrics with good washing, friction fastness and antibacterial properties; functional textile products with different properties can be produced by making use of the properties of tungsten and barium sulfate.

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