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Survey on the Antibacterial Effect of Silver Nanoparticles Deposited on Textile Fabrics

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Abstract

Background: *According to the recent studies, the antibacterial activities of silver nanoparticles (Ag-NPs) were studied on Gram-positive Staphylococcus aureus and Gram-negative Escherichia coli. In this study antibacterial effect of silver nanoparticles that used for coating textiles, on E.coli and S.aureus was investigated.*
Methods: *Silver nanoparticles were coated on textile fabric by corona treatment and the antibacterial properties of fabrics were quantitatively evaluated by using a Gram-positive bacterium S. aureus and Gram-negative bacterium E. coli.*
Results: *The textiles coated with silver nanoparticles had favorable antimicrobial effect against both E. coli and S. aureus. The value of antibacterial activity was appropriated with corona power and deposition that was used for absorption of Silver nanoparticle on samples.*
Conclusions: *These results suggest that silver nanoparticles could be used as an effective antibacterial material.*

Keywords: Silver nanoparticles, Staphylococcus aureus, Escherichia coli, Antibacterial activity.
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Introduction

Due to the prevalence of infectious diseases caused by different pathogenic bacteria and the development of antibiotic resistance, pharmaceutical companies and scholars have been conducting research for new antibacterial agents. Nanoscale materials have recently emerged as novel antimicrobial agents due to their high surface area to volume ratio and unique chemical and physical properties.[1,2]Nanotechnology is a rapidly growing field with its application in science and technology for the purpose of manufacturing new materials at the nanoscale level.[3]

Different types of nanomaterials such as copper, zinc, gold, and silver have been created. However, silver nanoparticles have been demonstrated to be the most effective and have antimicrobial efficacy against bacteria, viruses, and other eukaryotic microorganisms.3,4 In particular, silver ions have long been known to exert strong inhibitory and bactericidal effects as well as to have broad spectrum antimicrobial activities. Silver has been described as being "oligo-dynamic" because of its ability to exploit an antibacterial effect on products containing silver, principally due to its antimicrobial activities and low toxicity to human cells.

The ability of silver to prevent biofilm formation has been shown.[5] In addition, the number of silver nanoparticles per unit can be increased to maximize the antibacterial effects.[6]Recently, the use of nanoparticles due to their unusual nanooptical, chemical, electrical, and photoelectrochemical properties has been increasing.[7] The exact germicidal mechanism of silver nanoparticles is not fully understood. However, its antimicrobial mechanism can be explained as follows: metal ions generally annihilate or pass through the cell membrane and bond to the −SH group of cellular enzymes. Therefore, a critical reduction in enzymatic activity modifies the metabolism of the microorganism, which can inhibit cell growth and lead to cell death.[6] In addition, metal ions catalyze the production of oxygen radicals, which oxidize the molecular structure of bacteria. Silver ions can lead to protein denaturation and cell death because of their reaction with nucleophilic amino acid residues in proteins and its ability to bind to sulfhydryl, amino, imidazole, phosphate, and carboxyl groups of membrane or enzyme proteins.[8] Adherence of silver ions or nanoparticles to the bacteria, due to the electrostatic interaction with the negative charge of the bacterial cell wall, is one of the known mechanisms of cell death by silver nanoparticles.[2]

Silver nanoparticles have a significant antibacterial effect on Gram-positive and -negative bacteria as well as lethal effects on more than 650 bacterial species.[9] In addition, silver nanoparticles have lethal and inhibitory effects on a wide range of fungi and protozoa.[10]Textiles for the growth and survival of bacteria are a good place.; Microbial growths on textile materials not only harm the material but may also lead to adverse effects on the wear comfort. Unlike conventional finishing methods, which often do not furnish desired constant efficiency, it appears that functionalization with silver nanoparticles not only improves antimicrobial persistence but also does not remarkably change the fabric breathability and handle. The small sizes of silver nanoparticles (i.e., high surface to volume ratio) make them very reactive. In other words, a significant amount of silver atoms on the surface of nanoparticles is exposed to the surrounding medium, which provides an increase in bactericidal efficiency. Furthermore, small amounts of silver nanoparticles ensure high antimicrobial efficiency.[11] Staphylococcus aureus is a Gram-positive cocci that is often found in the nose, skin, and respiratory tract.[12] Bacteria are the most common cause of hospital infections that are resistant to numerous medications.[13] The removal and control of bacteria, particularly in hospital environments, is very important to prevent the spread of infections. Escherichia coli is a Gram-negative, opportunistic pathogen that can cause urinary tract infections and diarrhea.[13]Because S. aureus and E. coli are the most common infectious pathogens identified in hospital infections, the antimicrobial effect of fabric impregnated with silver nanoparticles on these microorganisms were studied.

Materials and Methods

Six pieces of textile fabrics (20 × 20 cm) were prepared. To eliminate surface impurities, the fabrics were fully cleaned and dried at room temperature. Corona treatment of fabrics was conducted at atmospheric pressure. Samples were placed on the electrode roll covered with silicon coating, rotating at a minimum speed of 2 m/min. The distance between electrodes was 3 mm.

Corona treatment under two different conditions (in terms of power and number of passages) was conducted: 1) power was 10,000 W and the number of passages was set to 50, 30, and 20 and 2) power was 5000 W and the number of passages was set to 50, 30, and 20.

Postoperatively, samples of silver nanoparticles were transferred to the dyeing units. Nanoparticle attachment to the fabric and dyeing was carried out concurrently. After 1 g of textile fabrics was treated by Corona, a dyeing bath that contained Nylosan Red) acidic dye) was prepared. Lastly, 13 dye-baths with two different concentrations of silver nanoparticles were prepared. Table 1 contains the details of each bathroom for Corona treatment.

The antibacterial properties of the fabrics were quantitatively evaluated by using S. aureus and E. coli. Tryptic soy agar (TSA) was used for cultivation of S. aureus and E. coli. TSA was prepared by suspending 40 g TSA in 0.5 L purified water and boiling the sample for a minute to completely dissolve the powder. Afterwards, TSA was autoclaved at 121°C for 15 min.

S. aureus and E. coli were cultivated on TSA and incubated for 16 h at 37°C. After incubation, a single colony from the plate was added to 10 mL sterile normal saline. Normal saline was diluted until we reached a turbidity of 0.5 McFarland. An aliquot of the solution (1 mL) was poured into a vial containing impregnated fabric (1 cm2 in size). The vials were incubated at for 24 h at 37°C. After incubation, 100 µL was removed from each vial and cultured on TSA plates for 16 h at 37°C. Lastly, the number of colonies on the control fabric (untreated fabric without silver) were compared to the number of colonies on the fabric loaded with silver nanoparticles. The strength of the antibacterial silver nanoparticles was calculated and expressed as a percentage.

Results

The number of colonies grown on the control plate was 300 and 600 colonies for S. aureus and E. coli colonies, respectively. The results of bacterial reduction after loading of silver nanoparticles on textile fabrics from 200 and 400 ppm colloids are shown in Tables 2 and 3, respectively.

Table 1. Details of each bathroom for corona treatment

Number of sample	Concentration of silver NPs	Power	Number of passage
1	200 ppm	5000	20
2			30
3			50
4		10000	20
5			30
6			50
7	400 ppm	5000	20
8			30
9			50
10		10000	20
11			30
12			50
13(control)	Without NPs	Without plasma	Without plasma

Table 2. The antibacterial impact of silver NPs onGram-negative bacteria (*E. coli*)

Number of sample	Concentration of silver NPs	Corona power	Number of passage	Antibacterial effect in percent
1	200ppm	5000	20	33
2			30	43
3			50	60
4		10000	20	60
5			30	60
6			50	78
7	400ppm	5000	20	33
8			30	53
9			50	73
10		10000	20	60
11			30	73
12			50	96

Table 3. The antibacterial impact of silver NPs on Gram-positive bacteria (S. *aureus*)

Number of sample	Concentration of silver NPs	Corona power	Number of passage	Antibacterial effect in percent
1	200ppm	5000	20	33
2			30	92.6
3			50	94.6
4		10000	20	60
5			30	94
6			50	100
7	400ppm	5000	20	80
8			30	92.5
9			50	95
10		10000	20	96
11			30	96
12			50	100

Discussion

Textiles can be a suitable substrate for growing microorganisms, particularly at suitable humidity and temperature when in contact with the human body.[14]To prevent an infection, the production of textiles with antibacterial properties is important. Increasing public concern about hygiene has been driving many studies on the antimicrobial modification of textiles.[14] However, using many antimicrobial agents has been avoided because of the possible harmful or toxic effects.[15] The application of inorganic nanoparticles and their nanocomposites would be a good alternative as antimicrobial agents.

Silver is considered a safer antimicrobial agent compared to some organic antimicrobial agents that are avoided because of the risk of their harmful effects on the human body.[16]Here, we examined the antibacterial effect of textile fabrics impregnated with silver nanoparticles on the growth of S. aureus and E. coli. Similarly to other published reports, we also identified the antibacterial properties of the silver nanoparticles. Our results showed that the antibacterial effect of textile fabric impregnated with silver nanoparticles is proportional to the amount of power and number of passages in Corona treatment.

Samples treated with power 10,000 W and 50 passages had the highest antibacterial effect against S. aureus and E. coli. In contrast, samples treated with power 5000 W and 20 passages had the lowest antibacterial effect. In addition, the antibacterial effect of silver nanoparticles on S. aureus was more than E. coli, which could be due to the cell wall structure and physiology of Gram-positive bacteria.

In this study, the effect of silver nanoparticles as an antibacterial agent on fabric was investigated. We found that the silver nanoparticles can inhibit bacterial growth. The coated fabrics have potential applications in wound dressing, bed lining, and as medicinal bandages. The coated fabrics can also be recommended to use in the disinfection of medical equipment, food industry and domestic cleaning. Furthermore, the materials used are inexpensive, non-toxic, and widely available.

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Conflict of Interest

The authors declare that They have no conflict of interest.

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