Environmental and Toxicology Management 1 (2021) 15-18

Contents lists available at journal2.unusa.ac.id

Environmental and Toxicology Management

journal homepage: www.journal2.unusa.ac.id/etm

Antimicrobial textile modified with silver nanoparticles in-situ synthesized using weed leaves extract

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Abstract

Silver nanoparticles (AgNPs) presence has a considerable impact on microbial growth. In this paper, AgNPs were deposited on the surface of four textiles to enhance the antimicrobial properties using immersion techniques. Immersion technique was selected since it was simple, no need high energies, and no additional equipment required. In addition, AgNPs were synthesized using in situ-bio technique which is non-toxic, harmless and eco-friendly approach. Four textiles were evaluated, such as TA, TB, TC, and TD. The finding projected that antifungal ability was correlated to the type of the textiles. TC textile has the large antimicrobial activity with 12.33 ± 2.08 mm of inhibition zone which followed by TD (16.00 ± 3.46 mm), TB (17.67 ± 7.09 mm), and TA (17.67 ± 6.65 mm). In addition, the surface binding of AgNPs on the fabric may be caused by -OH groups. It has a lone pair of electrons on the O atom, which can interact with AgNPs to form -OAg bonds.

Keywords :
antimicrobial, AgNPs, modified textile, in-situ biosynthesis

1 Introduction

Silver nanoparticles are important for a wide range of scientific and industrial processes since their exclusive and desirable physical, chemical, and ssbiological properties. Besides, AgNPs have many valuable properties, such us antibacterial, antifungal, and antiviral. Several industries used AgNPs for their products, such as cosmetics, detergents, paint industries, and textiles. In textile industries, AgNPs are used to inhibit the growth of bacteria and fungi.

Previous study has established that AgNPs inhibit the growth of microbes. Aini et al. (2019) showed AgNPs synthesized using *A. Conyzoides* have an average inhibition zone of B. aureus 1.33±0.06 mm and *E.coli* 1.27±0.06 mm, whereas AgNPs synthesized using *M. Micrantha* had an average inhibition zone of *B. cereus* 1.2±0.00 mm and *E. coli* 1.30±0.50 mm. Study (Lee et al., 2013) showed that 20 µg of AgNPs synthesis had a inhibition zone of 4.00±2.40 mm and 30 µg had a inhibition zone of 5.00±3.20 mm to against *P. capsica*, whereas to against *P. infestans* 20 ug of AgNPs synthesis had a inhibition zone of 5.00±1.60 mm and 30 ug had a inhibition zone of 5.00±1.50 mm. Another study showed the inhibition zone for all *Candida sp.*, such as *C. albicans* 12.00±3.00 to 15.00±2.00 mm, *C. glabrata* 12.00±2.00 to 17.00±4.00 mm, *C. krusei* 11.00±3.00 to 12.00±2.00 mm and *C. pseudotropicalis* 11.00±2.00 to 15.00±2.00 mm (Owaid et al., 2015).

Research to date has not yet determined the effect of time factors on inhibition zones. Time factors leading to inhibition zones remain speculative. Moreover, the time factor was needed in applications in various fields, such as textiles in medical applications.

Several methods were used for the synthesis of AgNPs in textiles, such as chemical methods, physical methods, and biological methods (Jain Mehata, 2017; Kumar et al., 2018; Raza et al., 2016). Chemical and physical procedures used for AgNPs synthesis are dangerous to the environment and require large amounts of energy. Different from chemical and physical methods, the green synthesis method has several advantages, such as simple, non-toxic, affordable and environmentally friendly (Bagherzade et al., 2017; Khalil et al., 2014). In green synthesis, natural reducing and stabilizing agents were needed, for example Lee et al. (2013) using cow milk as reducing and stabilizing agents. Reducing agent was needed to reduce Ag^{+} to Ag^{0} (Fadlilah et al., 2019). Whereas, stabilizing agent was needed to prevent agglomeration (Syafiuddin et al., 2018).

The use of cow milk as reducing and stabilizing agents to synthesize AgNPs was a less appropriate alternative. Cow milk can still be consumed by the public. As an alternative, other organic materials can be used as reducing and stabilizing agents, such as weeds. The use of weeds increased the value of research use. In addition, the use of weeds can protect the environment from the organic waste of the weeds themselves. Also, the application of AgNPs on textiles was not yet clear. Due to the limitations, this study was designed to synthesize AgNPs using weed leaves extract against *Aspergillus sp.* In this study, AgNPs are applied to four different types of textiles.

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Email Address : anisaratnasari72@gmail.com
https://doi.org/10.33086/etm.v1i3.2502
Received from 24 November 2021;
Received in revised from 29 November 2021;
Accepted 29 November 2021;
Available online 30 November 2021;

2 Materials and method

2.1 Materials

Wild weed leaves were collected around Universiti Teknologi Malaysia. Whatmann paper pore size 11 um (Whatman cellulose filters, Sigma-Aldrich,USA) was used as filter. Ionized water was used for synthesis process. Aspergillus sp. fungus were obtained from the Faculty of Biosciences and Medical Engineering, Universiti Teknologi Malaysia. Further, Malt extract agar (Merck KGaA, Darmstadt, Germany) powder was used. Silver nitrat salt ($AgNO_3$, QReC, Auckland, New Zealand) was used. A stock solution of $AgNO_3$ 0.1 M was prepared by dissolving 1.698 g/100 mL ionized water. 4 types of textiles were used in this study which named TA, TB, TC, and TD. Parafilm were used for sealing petri dish.

2.2 Instrumentation

The analytical scale was recorded at room temperature using Mettler Toledo MS204S. Laminar Airflow studies were performed using ESCO Laminar Airflow Cabinet to stabilize sterile state. Autoclave were used Hirayama HICLAVE to decontaminate certain biological waste. Glass Filtration Vacuum Set was used for filtering process. For drying process, oven was performed using Memmert Oven. Refrigerator was setted at 7^{o}C.

2.3 Preparation of leaves extract

10 g of wild weed leaves were measured. To relieve impurities, fresh leaves were washed three times for each using tap water and distilled water. leaves and 200 mL ionized water were put in beaker glass. The mixture was heated to 80 ^{o}C for 40 minutes. The mixture then cooled at the room temperature. To obtain a pure leaves extract, the mixture was filtered using filter paper.

2.4 Preparation of textile

For this study, 4 types of textiles were used. The four types of textiles were cut in a circle shape and diameter of 8 mm. The textiles rinsed using tap water three times. Then, they put and boiled using ionized water. After boiling, the textiles drain in room temperature. Then, the textiles were dried in the oven at 50 ^{o}C for 10 minutes.

2.5 Antifungal textiles

For the purpose of attached AgNPs to textile, textiles soaked in 5 ml solution of AgNPs for 30 minutes into beaker glass at 100 rpm. Then, 5 ml weed extract poured carefully poured into the textiles at 50 ^{o}C. The mixture stirred at 100 rpm. The mixture heated at 50 ^{o}C for 15 minutes. To dry the textiles, textiles put on oven air-dried at 50 ^{o}C for 15 minutes. The same procedure was carried out for another type textiles.

2.6 Preparation of media cultures

To maintain a sterile state, laminar airflow and autoclave were used in making media and fungal culture. Measured 27.6 g of Malt extract agar and 575 mL of water in a reagent bottle, then mixture gently. The mixture was melted and sterilized using an autoclave for 50 minutes at 121 ^{o}C. Place melted agar in reagent bottle, parafilm and petri dish in the laminar airflow. Melted agar was poured into the petri dish and allowed to cool. After cooled, petri dishes were sealed tightly using parafilm.

2.7 Antifungal assay and inhibition zone

The plate and antifungal textiles were sterilized using an autoclave in 50 minutes. Then, fungal colonies were carefully grown in the middle of plate. The textiles were aseptically put to a plate. The textiles were placed in a triangle point on the surface of plate. Plate was incubated at room temperature for 2 days. Then, the inhibition zone was measured.

3 Result

3.1 AgNPs deposition

Numerous of textiles have an elongated cross-section like a twisted ribbon, such as cotton, polycotton, silk. Different types of textiles have different fiber content. For instance, the largest content of cotton is cellulose. Polycotton is fabricated from a mixture of polyester and cotton, meanwhile, silk contains of fibroin and sericin. Mostly, fibers have high absorption and is hydrophilic (Noerati, Ichwan, and Sumihartati, 2013). For cotton and polycotton, they have -OH group, which has a lone pair of electrons on the O atom that can interact with silver nanoparticles to form an -OAg bond (Erviana et al., 2017). For silk, it has the group of -H, $-CH_3$, $-CH_2OH$ dan $-CH_2C_6H_5OH$ (Hearle Morton, 2008). In addition, textile deposited with AgNPs was shown to have antimicrobial properties (Ahmed Emam, 2016).

Four different textiles, TA, TB, TC, and TD, have been deposited with AgNPs by using wild weed leaves extract as green technique. The color of textile with AgNPs turned darker which indicated that AgNPs had been deposited. AgNPs can be deposited on the surface of the textile since the interaction of -OH group. Thus, it can form -OAg bond.

3.2 Antimicrobial examination

Table 1 presents zone of inhibition of the treated textiles against *Aspergilus sp* as microbes. It was found that the treated TA had zone of inhibition by 12.33 ± 2.08 mm. In addition, TB, TC, and TD performed zone of inhibition by 16.00 ± 3.46 mm, 17.67 ± 7.09 mm, and 17.67 ± 6.65 mm, respectively. In general, the highest zone of inhibition was performed by the treated TC and followed by TD, TB, and TA.

Previous study prescribed that inhibition zone of AgNPs textile was 16.97 ± 0.12 mm, 18.03 ± 0.15 mm, 13.73 ± 0.06 mm, 15.77 ± 0.06 mm, and 14.07 ± 0.25 mm when they were tested against *S. aureus*, *B. subtilis*, *E. coli*, *P. aeruginosa*, and *K. pneumoniae*, respectively (Balakumaran et al., 2016). In addition, carbenzim addition on AgNPs synthesis against fungal strain *Colletotrichum gloeosporioides* enhanced the inhibition zone up to 59 mm from 22 mm for the treatment without carbenzim addition (Shivamogga Nagaraju et al., 2020).

Table 1 Inhibition zones of four different type of textiles

Textiles	**Inhibition Zone (mm)**	
	Control	AgNPs treatment
TA	NA	12.33 ± 2.08
TB	NA	16.00 ± 3.46
TC	NA	717.67 ± 7.09
TD	NA	17.67 ± 6.65

3.3 Antimicrobial mechanisms

Several studies have reviewed the antimicrobial activity, including antifungal AgNPs by three general mechanisms, namely (i) direct interference with cell membranes; (ii) absorption of free silver

ions followed by disruption of DNA replication; and (iii) the occurrence of cell respiratory system disorders, impaired ATP production and the formation of reactive oxygen species (ROS) by AgNP and silver ions (Pereira et al., 2014; Ratnasari et al., 2020).

AgNP can penetrate cell walls. AgNPs inactivate sulfhydryl thiol groups in cell wall cells (Alsammarraie et al., 2018). In addition, AgNPs interfere with enzymes and lipids in cell membranes that cause cell lysis (Prasher et al., 2018). Ag^+ ions can destabilize K^+ ions and cause K^+ ions to be released from the cytoplasm (Prasher et al., 2018). In addition (Figure 1), AgNPs can bind to and inactivate functional enzyme groups (Zhao et al., 2018). AgNPs ions can interact with the cell cytoplasm (Żarowska et al., 2019). This interaction is in the form of electrostatic interactions between negatively charged cell membrane ions and positively charged silver ions. This interaction causes inhibition of DNA replication (Figure 1). As a result, degradation occurs and microbial growth is inhibited (Durán et al., 2016; Zhao et al., 2018).

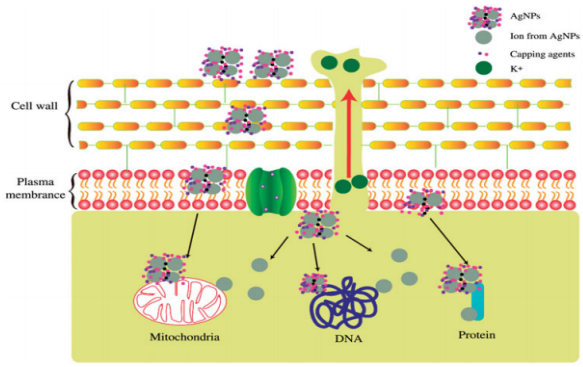

Figure 1 Antimicrobial AgNPs mechanisms (Zhao et al., 2020)

AgNPs can affect respiratory enzymes in microbes. Disturbances in these respiratory enzymes affect normal cell metabolism (Haroon et al., 2019). Disruption of respiratory enzymes occurs when AgNPs inhibit the activity of respiratory chain dehydrogenases in microbes. This inhibition will cause disruption of the microbial respiratory chain which results in the cessation of respiration (Zheng et al., 2018).

AgNPs can also inhibit microbial growth by influencing the formation of Adenosine triphosphate (ATP), an important energy source for microbial cells (Yamanaka et al., 2005). Ag^+ ions released from AgNPs can penetrate cell walls and interact with ribosomes (Jalal et al., 2018). As a result, these ions will inhibit the expression of enzymes and proteins (Figure 1), which are required for ATP production. In addition, these ions will also affect the respiratory chain by reducing electron transfer and ATP formation in cells (Zheng et al., 2018).

AgNPs can produce free radicals ROS (reactive oxygen species) which cause oxidative damage to proteins caused by increased permeability in the membrane, and inactivation of lactate dehydrogenase laktat (Durán et al., 2016). ROS produced by AgNPs can inhibit the nitrification process in nitrifying microbes. In addition, AgNPs can oxidize DNA (Figure 1). DNA damage will damage bacterial cells because it causes mutations in the next generation (Zheng et al., 2018).

4 Conclusion

In general, therefore, it seemed that the modification of antimicrobial textile could be enhanced using biosynthesis of AgNPs. AgNPs were deposited on the various textiles. Result presented that TC, TD, TB, and TA textile has an antimicrobial property with 12.33 ± 2.08, 16.00 ± 3.46, 17.67 ± 7.09, and 17.67 ± 6.65 mm of inhibition zone. Currently, antifungal ability was related to the type of the textiles. The surface bonding AgNPs on textile was possibility caused by the -OH group. It has a lone pair of electrons on the O atom that can interact with silver nanoparticles to form –OAg bonds.

Declaration of competing interest

The authors declare no known competing interests that could have influenced the work reported in this paper.

Acknowledgments

The authors thank Institut Teknologi Sepuluh Nopember (ITS) for facilitating the work.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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