Research Article

Fabrication of Antimicrobial Perspiration Pads and Cotton Cloth Using *Amaranthus dubius* Mediated Silver Nanoparticles

M. Jannathul Firdhouse and P. Lalitha

Department of Chemistry, Avinashilingam Institute for Home Science and Higher Education for Women,
Coimbatore 641043, Tamil Nadu, India

Correspondence should be addressed to P. Lalitha; goldenlalitha@gmail.com

Received 30 May 2013; Accepted 2 September 2013

Academic Editor: Alberto Ritieni

Copyright © 2013 M. J. Firdhouse and P. Lalitha. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Silver nanoparticles prepared through a simplistic method using the aqueous extract of *Amaranthus dubius* were fabricated on perspiration pads and cotton cloth samples to obtain antibacterial textile materials by two different fabrication methods. The antibacterial activity was investigated against the bacteria *Corynebacterium* which is commonly present in sweat. Silver nanoparticles that serve as antibacterial agents, against pathogenic bacteria, have gained increased applications in medical devices, textile fabrics, and food industry and hence the result of this study would be a welcomed option.

1. Introduction

The development of new antibacterial fibers to protect wearers is being paid more consideration due to the infectious diseases sourced by different pathogenic bacteria rather than the quality and durability of textiles should be replaced by preferably the quality and durability of textiles [1, 2]. Modern and innovative approaches have to be implemented to bring out new formulations based on the metallic nanoparticles with antimicrobial properties [3]. Nanometal oxide film coated on the fabrics possesses promising antimicrobial activities. The nosocomial infections can be prevented by using antibacterial fabrics in the form of medical clothes, protective garments, bed spreads, and so forth [4, 5].

Silver nanoparticles can be synthesized by various methods like photochemical reduction, chemical reduction, heat evaporation, biological synthesis by using plant extracts, microorganisms, and numerous other methods [6]. Production of silver nanoparticles with plant extracts endorses green chemistry principles. Silver metal as such exhibits excellent antimicrobial properties and finds ample range of applications in diverse fields [7]. The silver nanoparticles synthesized from *Cajanus cajan* [8], *Boswellia ovalifoliolata*, *Shorea tumbuggaia* [9], *Aspergillus niger* [10], and *Ficus carica* [11] are reported for its good antibacterial activity against *E. coli* and *S. aureus*.

In view of the significance of silver nanoparticles, an attempt has been made in the present study to synthesize silver nanoparticles using the aqueous extract of *Amaranthus dubius*. The stability of the nanosilver particles would be analyzed by zeta potential measurements. Considering the use of the synthesized nanosilver particles, an effort is made in the current study to fabricate cotton cloth samples and perspiration pads by sonication and dipping methods and study its antibacterial activity against *Corynebacterium* sp.

2. Materials and Methods

2.1. Preparation of the Extract. Fresh plant of *Amaranthus dubius* (40 g) was washed thrice with double distilled water, cut into small pieces, and boiled with 200 mL water for 5–10 minutes. The solution was filtered using Whatman filter paper. The extract (150 mL) thus obtained was concentrated using Rota vapour (Equitron make) and refrigerated for further use.

2.2. Silver Nanoparticles Synthesis. The preparation of silver nanoparticles using *Amaranthus dubius* done earlier in our lab is reported [12]. The concentration of the silver nitrate and aqueous extract is increased in order to produce nanosilver in bulk quantity and also to maintain the uniformity in particle size and shape. The formation of silver nanoparticles was

monitored by the colour change of solutions from yellow coloured to reddish brown and finally dark brown. The formation of silver nanoparticles was confirmed by further characterization of the solutions.

2.3. Characterization of Synthesized AgNPs. The UV-visible absorption spectrum of nanosilver was recorded using Double beam spectrophotometer-2202 (Systronics). The particle size and zeta potential of the synthesized silver nanoparticles were analyzed using Zetasizer Ver. 6.32 (Malvern; MAL1037088) and maintained at a temperature of 30°C for 70 s by disposable sizing cuvette.

2.4. Preparation of Samples for Fabrication. Two different textiles materials, namely, a cotton cloth and perspiration pads, were chosen for the study. The samples were sonicated for 15 min in double distilled water and washed several times to remove the starch and gel in the perspiration pads. The washed samples were dried in hot air oven maintained at a temperature of 60°C. Both the cotton cloth and perspiration pad samples after pretreatment were cut into small pieces of size $2 \times 2 \text{ cm}^2$. The samples were weighed before fabrication and weights were recorded in triplicate at three different time periods.

2.5. Coating of Silver Nanoparticles onto Textile Samples. The synthesized silver nanoparticles were fabricated on cotton cloth (CD) and perspiration pads (PD) by means of dipping and sonication methods. The samples were dipped in 10 mL nanosilver solution and kept for 1 h at room temperature. After 1 h, the solution was transferred and the samples were dried at 60°C. The dried samples were weighed and the difference in weight before and after coating was calculated.

In sonication method, the cotton cloth samples (designated CSH, CSO & CSM) and perspiration pad samples (designated PSH, PSO & PSM) were dipped in 10 mL nanosilver solution and sonicated using Ultrasonics (1.5 L (H)) at different time intervals (30 min, 60 min, and 90 min), respectively. After the stipulated time intervals, the solutions were transferred and the samples were dried at 60°C. The dried samples were weighed and the difference in weight before and after coating was calculated.

Ciprofloxacin was used as standard and was also coated on cotton cloth and perspiration pad by sonication for 30 min.

2.6. Antibacterial Study. The antibacterial activity was carried out for the fabricated cotton cloth and perspiration pad samples against *Corynebacterium* sp. according to AATCC 147 standards by agar well diffusion method.

2.6.1. Agar Well Diffusion Method

(a) Preparation of Inoculums. Preserved slant cultures were used to prepare the inoculums required for the experiment. The inoculums were then standardized by varying the turbidity of the culture pertaining to that of McFarland standards.

The turbidity of the culture was adjusted by the addition of sterile saline to get necessary turbidity.

(b) Preparation of Sterile Swabs. Cotton wool swabs on wooden applicator were prepared. These were sterilized by autoclaving. Culture tubes were used for packing the swabs for later use.

(c) Sterilization of Forceps. The forceps used in the study were sterilized using alcohol.

(d) Disc Method to Determine the Zone of Inhibition. The standardized inoculums were inoculated in the aseptic plates prepared earlier by dipping a sterile swab in the inoculums and rotating the swab firmly against the side of the culture tube. The swab was then streaked through the entire surface of the medium 3 times rotating the plate through an angle of 60° after each application. The swab was then passed round the rim of the agar surface. The inoculums were dried at room temperature with the lid in a closed condition.

The materials to be fabricated, namely, a cotton cloth and perspiration pads were sterilized by placing under UV. The samples, were then cut into sizes of $2 \times 2 \text{ cm}^2$ and weighed. These samples each of $2 \times 2 \text{ cm}^2$ were placed in Petri dishes with the help of sterile forceps. Then Petri dishes were refrigerated at 4°C for 1 hour after which they were incubated at 37°C for 24 hours. The zones of inhibition produced by the samples were measured using a scale. The average of two diameters of each zone of inhibition was recorded.

3. Results and Discussion

The aqueous extract of *Amaranthus dubius* (1 mL) was treated with different concentrations (6 mL, 7 mL, 8 mL, 9 mL, and 10 mL) of silver nitrate solution (10 mM) and sonicated (Ultrasonics 1.5 L (H)) for 10–15 min. The visible colour change of the solutions from yellow to brown indicated the presence of silver nanoparticles. The UV-visible absorption spectra showed an absorption band at 425 nm (Figure 1) close to surface Plasmon resonance band of silver nanoparticles. The particle size analyzer revealed the size of synthesized silver nanoparticles to be 179 nm (Figure 2). The zeta potential value of nanosilver synthesized was found to be less than -25 mV indicating high degree of stability (Figure 3). After characterization of silver nanoparticles, a higher concentration (10 mL) of silver nitrate with 1 mL of aqueous extract was selected for coating the chosen fabrics. In the previous synthesis [12], the particle size was reported to be less than 100 nm. As the concentration of silver increases, the particle size also was found to increase. Thus, the concentration variation plays an important role in the size of the nanoparticles. The SEM image of silver nanoparticles fabricated onto the cotton cloth sample is shown in Figure 4.

The results of the study of fabrication of silver nanoparticles on cotton cloth (CD, CSH, CSO & CSM) and perspiration pad (PD, PSH, PSO & PSM) samples by dipping and sonication methods are shown in Table 1. From Table 1, it is apparent that the sonication method of fabrication results in double the amount of coating obtained from dipping method

FIGURE 1: UV-visible absorption spectra of synthesized silver nanoparticles.

FIGURE 2: Particle size distribution of synthesized silver nanoparticles.

for 60 min. Hence, sonication method was adopted for fabrication of samples in increased time intervals. Comparing the results obtained from sonication method at three different time intervals showed that the amount of coating onto the samples was more in 90 min (5 mg) than in the other two time intervals. There is no much difference observed in the amount of coating obtained for 60 min and 30 min. Thus, the sonication method results in appreciable quantity of coating compared to dipping method onto both the cotton cloth and perspiration pad samples. Sonication results in higher dispersion of the particles and hence more diffusion onto the substrate is feasible. This may be the reason why sonication affords enhanced results compared to the conventional method of fabrication, namely, dipping. The nature of the textile material is also a contributing factor. Perspiration pads absorb more than cotton cloth and hence the greater deposition of nanosilver onto the perspiration pads.

The fabricated cotton cloth and perspiration pad samples were tested for their antibacterial activity against *Corynebacterium* sp. (NCIM 2640) according to AATCC 147 standards using agar well diffusion method. After the incubation time, a clear zone of inhibition was observed against the tested organism by the samples (Table 2 and Figure 5). According to AATCC 147 interpretation, the presence of zone of inhibition indicates that the antibacterial is leaching into the agar. Also, it is required that no growth of bacteria be noted under or above the test samples studied.

FIGURE 3: Zeta potential distribution of synthesized silver nanoparticles.

FIGURE 4: SEM image of nanosilver fabricated onto the cotton cloth sample.

The results of the present study revealed that no growth of bacteria was noted under and above the test samples indicating the success of the study. The zone of inhibition was comparatively more for the perspiration pad samples than cotton cloth samples. The pronounced effect noted in the case of perspiration pad samples may be due to the greater amount of silver nanoparticles being coated than in cotton cloth.

The zone of inhibition values for the fabricated perspiration pad and cotton cloth samples at time intervals of 60 min and 90 min was same. This implies that the amount of silver nanoparticles coated onto the chosen fabrics plays a vital role in the antibacterial activity. There was no bacterial growth on the upper and lower surfaces of the cotton cloth and perspiration pad samples which were fabricated by means of sonication for 90 min and 60 min, respectively. The zone of inhibition values and clear surfaces of the samples revealed that the nanosilver fabricated at a higher time interval exhibited more resistance against sweat bacteria. The nanosilver synthesized using aqueous extract of *Amaranthus dubius* possesses excellent antibacterial efficacy compared to the reported literature [13] using the same plant extract alone.

TABLE 1: Comparative results of methods used in the fabrication of AgNPs on the cotton cloth and perspiration pad samples.

S. No.	Method	Time (minutes)	Weight of the cotton cloth (g)			Weight of the perspiration pad (g)		
			Before	After	Difference in weight	Before	After	Difference in weight
1.	Dipping	60	0.05250	0.05364	0.00114	0.0451	0.04838	0.00328
		30	0.05070	0.05275	0.00205	0.0479	0.05190	0.00409
2.	Sonication	60	0.05160	0.05390	0.00230	0.0425	0.04704	0.00454
		90	0.05170	0.05664	0.00494	0.0425	0.04957	0.00707
3.	Control	30	0.05315	0.05485	0.00170	0.0330	0.03551	0.00242

Bold values refer to the highest amount of coating onto the cotton cloth and perspiration pads.

FIGURE 5: Antibacterial activity of the synthesized silver nanoparticles fabricated onto perspiration pads.

TABLE 2: Zone of inhibition of synthesized silver nanoparticles against *Corynebacterium* sp.

Sample	Zone of inhibition (mm)
CSH	32
CSO	34
CSM	35
CD	31
PSH	34
PD	31
PSO	36*
PSM	36*
Control C	54
Control P	60*

* Shown in Figure 5.

4. Conclusion

The silver nanoparticles were synthesized using the aqueous extract of *Amaranthus dubius* by two different methods at three different time intervals and characterized. The particle size distribution analyzer confirmed the size of the nanosilver to be 179 nm. The zeta potential of synthesized AgNPs revealed its high degree of stability. Antibacterial study of the synthesized silver nanoparticles fabricated on the cotton cloth and perspiration pad samples shows high resistance towards sweat bacteria. Hence, this green synthesis of nanoparticles

seems to be a promising and effective antibacterial agent and it can be applied in textiles, medical devices, and pharmaceuticals.

Acknowledgments

The authors are sincerely thankful to the Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, Tamil Nadu, for providing research facilities and to Karunya University for recording Zeta sizer. The assistance of the KMCH College of Pharmacy in antibacterial studies is kindly acknowledged.

References

- [1] S. Shirley, A. Dayanand, B. Sreedhar, and S. G. Dastager, "Antimicrobial activity of silver nanoparticles synthesized from novel *Streptomyces* species," *Digest Journal of Nanomaterials and Biostructures*, vol. 5, no. 2, pp. 447–451, 2010.
- [2] P. Gupta, M. Bajpai, and S. K. Bajpai, "Investigation of antibacterial properties of silver nanoparticle-loaded poly (acrylamide-co-itaconic acid)-grafted cotton fabric," *Journal of Cotton Science*, vol. 12, no. 3, pp. 280–286, 2008.
- [3] M. A. Ansari, H. M. Khan, A. A. Khan et al., "Evaluation of antibacterial activity of silver nanoparticles against MSSA and MRSA on isolates from skin infections," *Biology and Medicine*, vol. 3, no. 2, pp. 141–146, 2011.
- [4] K. Kulthong, S. Srisung, K. Boonpavanitchakul, W. Kangwansupamonkon, and R. Maniratanachote, "Determination of silver nanoparticle release from antibacterial fabrics into artificial sweat," *Particle and Fibre Toxicology*, vol. 7, article 8, 2010.
- [5] M. El-Nahhal, S. M. Zourab, F. S. Kodeh, M. Selmane, I. Genois, and F. Babonneau, "Nanostructured copper oxide-cotton fibers: synthesis, characterization, and applications," *International Nano Letters*, vol. 2, no. 14, pp. 1–5, 2012.
- [6] M. Awwad and N. M. Salem, "Green synthesis of silver nanoparticles by Mulberry leaves extract," *Nanoscience and Nanotechnology*, vol. 2, no. 4, pp. 125–128, 2012.
- [7] P. Kumar, S. S. Selvi, A. L. Prabha, K. P. Kumar, R. S. Ganeshkumar, and M. Govindaraju, "Synthesis of silver nanoparticles from *Sargassum tenerrimum* and screening phytochemicals for its antibacterial activity," *Nano Biomedicine and Engineering*, vol. 4, no. 1, pp. 12–16, 2012.
- [8] V. B. Nagati, R. Koyyati, M. R. Donda, J. Alwala, and K. R. Kundle, "Green synthesis and characterization of silver nanoparticles from *Cajanus cajan* leaf extract and its antibacterial

- activity," *International Journal of Nanomaterials and Biostructures*, vol. 2, no. 3, pp. 39–43, 2012.
- [9] N. Savithramma, M. Linga Rao, K. Rukmini, and P. Suvarnalatha Devi, "Antimicrobial activity of silver nanoparticles synthesized by using medicinal plants," *International Journal of ChemTech Research*, vol. 3, no. 3, pp. 1394–1402, 2011.
- [10] G. Sagar and B. Ashok, "Green synthesis of Silver Nanoparticles using *Aspergillus niger* and its efficacy against Human pathogens," *European Journal of Experimental Biology*, vol. 2, no. 5, pp. 1654–1658, 2012.
- [11] P. P. Singh and C. Bhakat, "Green synthesis of gold nanoparticles and silver nanoparticles from leaves and bark of *Ficus Carica* for nanotechnological applications," *International Journal of Scientific and Research Publications*, vol. 2, no. 5, 2012.
- [12] M. J. Firdhouse and P. Lalitha, "Phyto-assisted synthesis and characterization of silver nanoparticles from *Amaranthus Dubius*," *International Journal of Applied Biology and Pharmaceutical Technology*, vol. 3, no. 4, pp. 96–101, 2012.
- [13] A. Gebrehiwot and C. G. Unakal, "Effect of aqueous and ethanol extracts of *Ocimum lamiifolium* and *Amaranthus dubius* against bacteria isolated from clinical specimen," *International Journal of Pharmacy & Industrial Research*, vol. 3, no. 1, pp. 10–14, 2013.