

RESEARCH PAPER

Exploring Potentials of *Arum Elongatum* for Synthesizing Silver Nanoparticles: Antibiofilm Effect on *Uropathogenic* Bacteria

Raziyeh Mohamadpoor, Fereshteh Jookar Kashi *

Department of Cell and Molecular Biology, Faculty of Chemistry, University of Kashan, Kashan, Islamic Republic of Iran

ARTICLE INFO

Article History:

Received 08 October 2025

Accepted 10 March 2026

Published 01 April 2026

Keywords:

Antibacterial activity

Antibiofilm

Arum elongatum

Cytotoxicity

ABSTRACT

Silver nanoparticles are widely applied in industrial and biomedical fields. Also, the silver nanoparticles show a capability against bacterial drug resistance bacteria. The unique final properties of the nanoparticle depend on the type, size, and shape of nanoparticles. We used leaves extract *Arum elongatum* in the present study to synthesize silver nanoparticles. The synthesized AgNPs were identified using UV-Vis, SEM, XRD, and FT-IR analysis. The UV-Vis analysis of AgNPs has exhibited an absorbance peak at 430 nm. The crystalline structure of the silver nanoparticles was determined by XRD analyses. The SEM analysis results indicated spherical shape aggregates with an average particle size between 9-11nm. Afterward, the antibacterial properties of the nanoparticles were studied by broth microdilution methods. The nanoparticles showed the antibacterial effect on all the pathogenic strains with minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) in the range of 0.0312 ± 0.00 to 0.5 ± 0.00 and 0.125 ± 0.00 to $2 > \pm 0.00$ mg/ml, respectively. The evaluation of antibiofilm activities of AgNPs against uropathogenic bacteria showed a potent biofilm inhibitory. Further, the cytotoxicity of AgNPs was determined using a brine shrimp lethality assay, and the LC_{50} value was 200 mg/ml.

How to cite this article

Mohamadpoor R., Jookar Kashi F. Exploring Potentials of *Arum Elongatum* for Synthesizing Silver Nanoparticles: Antibiofilm Effect on *Uropathogenic* Bacteria. J Nanostruct, 2026; 16(4):1823-1832. DOI: 10.22052/JNS.2026.02.033

INTRODUCTION

A Japanese scientist, Norio Taniguchi from Tokyo University, introduced nanotechnology [1]. Nanotechnology is a science that researches particles and materials at the nanoscale (1-100 nm) [2,3]. The advantage of nanoscale size is the high surface-to-volume ratio [4,5]. Nanoscale features are often incorporated into bulk materials. They have a large surface-to-volume ratio [6], bio-molecular detection, diagnostics [7], catalysis [8], microelectronics [9], sensing devices and targeting of drugs to cancer cells [10].

* Corresponding Author Email: jookar@kashanu.ac.ir

The shape, size, and structural properties of NPs strongly depend on synthetic methods. During the last decades, many approaches have been utilized to synthesize NPs classified into three groups: chemical, physical and biological [2,11]. Evaporation-condensation and chemical reduction synthesize metal nanoparticles [12]. Physical and chemical processes can successfully produce nanoparticles. These expensive, high-energy methods are potentially hazardous to humans, animals, and the environment [13].

Nowadays, plant extracts synthesize green



This work is licensed under the Creative Commons Attribution 4.0 International License.

To view a copy of this license, visit <http://creativecommons.org/licenses/by/4.0/>.

nanoparticles [14,15]. The green synthesis of metal particles is environmentally friendly and cost-effective. Moreover, it does not require high temperatures, pressures, energy, and toxic chemicals [16,17]. The plant extract of roots, stem, leaves, and fruit has been utilized to biosynthesize metal and metal oxide nanoparticles [18-20]. The nanoparticles can be synthesized by proteins, amino acids, enzymes, polysaccharides, alkaloids, tannins, phenolics, terpenoids, glycosides, and benzenoids in the plant extract. These compounds may reduce, capping, and stabilize agents in nanoparticle synthesis [21-23].

Metal nanoparticles are important among nanoparticles due to their antimicrobial properties [1,20,24,25]. Medicinal application is one of the important aspects of nanotechnology. Infectious diseases are the major challenges for humans, and multidrug-resistant bacterial are a severe threat to human health worldwide [26,27]. Silver nanoparticles were selected to overcome these problems due to their multiple medical functions. Silver nanoparticles have exhibited different biological activities such as anti-inflammatory, antifungal, anticancer, antiplasmodial, and antimicrobial activity [26]. The antibacterial ability of smaller Ag nanoparticles is higher than that of larger Ag nanoparticles [21,28,29]. This study aimed to synthesize AgNPs through *A. elongatum* extract and evaluate their biological activity, including antimicrobial, anti-biofilm, and cytotoxicity.

MATERIAL AND METHODS

Silver nitrate (AgNO_3 , 99.9%) was prepared from Merck. The culture medium includes nutrient agar (NA), nutrient broth (NB), tropic soy broth (TSB), and supplements purchased from Merck. All chemicals and solvents used in this study were purchased from Merck. Brine shrimp eggs used in this study were purchased from Inc., Salt Lake City, Utah 84126.

Collection and preparation of aqueous leaves extract

Arum elongatum leaves were collected from Mount Dena in Kohgiluyeh and Boyer-Ahmad province. At first, the leaves were washed with distilled water and followed shade-dried. Then, the powder (3.5 g) was added to water (200 ml) and heated at 40 °C for 15 min [30]. After filtration, the solution was used for the nanoparticle synthesis

reaction.

Synthesis of silver nanoparticle

For the synthesis process, 10 ml of the aqueous extract was added to AgNO_3 (1mM) and incubated at 60 °C. The changing color of the solution from colorless to dark brown indicated the synthesis of silver nanoparticles. After 24 h, the nanoparticles were isolated by centrifugation at 12000 rpm for 15 min at 24 °C and washed with double distilled water three times. The clear supernatant solution was discarded, and the pellet was dried and stored until further study.

Characterization of silver nanoparticles

The formation of AgNPs was measured by a Shimadzu UV-1800 spectrophotometer at 300-700 nm. The FT-RI spectrum was determined by the FT-IR spectrophotometer (Shimadzu-8400). The presence of biomolecules in aqueous extracts and silver nanoparticles was selected in the 4000-400 cm^{-1} range at a resolution of 4 cm^{-1} . The surface morphology and size of synthesized AgNPs were evaluated using a scanning electronic microscope (SEM). The crystal structure of AgNPs was evaluated using a Philips Xpert pro-XRD system. The average crystallite size of the AgNPs was calculated with the Debye-Scherrer equation: $D = (k\lambda) / (\beta)$.

Antibacterial activity

Sixteen strains were collected from Qom Hospital, Iran, including *Escherichia coli*, *Staphylococcus aureus*, and *Klebsiella pneumoniae*. The minimum inhibitory concentration (MIC) was estimated using the broth microdilution procedure [31]. First, the concentration ranges of the AgNPs (1, 0.5, 0.25, 0.125, 0.0625 and 0.0312 mg/ml) were prepared. Afterward, 100 μl of each dilution was added to the wells containing 95 μl of TSB. Then, 5 μl of the bacterial suspension was adjusted to 0.5. MacFarland was inoculated to each well. The microplates were incubated at 37 °C for 24 h. Moreover, 195 μl of TSB and 5 μl of the suspension were applied as a control. The MIC value was determined as the lowest concentration of the AgNPs applied for inhibiting the growth of microorganisms. However, minimal bactericidal concentration (MBC) was measured by inoculating 5 μl from the clean well on nutrient agar. MBC was defined as the lowest concentration in which growth was observed.

Anti-Biofilm of AgNPs

The bacterial strains collected from patients with urinary tract infections in different care units of Qom Hospital (Iran) were selected because these strains have the biofilm-forming ability. The anti-biofilm activity of the AgNPs was measured using a microtiter plate assay [32].

The bacterial suspension adjusted to 0.5 MacFarland was diluted 1:100 in TBS medium. The suspension was then added to 96-well microplate (100 μ l per well). Also, 100 μ l of AgNPs solution (2 mg/ml) was added to each well. After incubation for 24h at 37 $^{\circ}$ C, the suspensions were removed from each well and washed twice with phosphate-buffered saline (PBS) to discard the planktonic cells. Then, methanol (200 μ l) was added to each well. After 20 min, all wells were washed with PBS; the adherent cells fixed in each well were stained with 1% crystal violet for 5 min and discarded by inversion. Then, the wells were rinsed with PBS. At the last stage, 95% ethanol was added for 5 min, and OD of the samples was recorded at a wavelength of 570 nm using a spectrophotometer.

Cytotoxicity assay

The cytotoxic activity of the AgNPs was

evaluated using the brine shrimp lethality test (BST). The different salts were resolved in one liter of distilled water NaCl (23 g), $MgCl_2$ (11 G), $NaSO_4$ (4g), $CaCl_2$ (1.3 g), and KCl (0.7 g). *Artemia salina* eggs were hatched after 48 h incubation at 37 $^{\circ}$ C under strong aeration and illuminations. After two days, when *A. salina* eggs were ready, ten larvae were collected and transferred into each tube containing 5ml of sea salt water and different concentration of the nanoparticles. The negative control contained seawater and ten larvae. Vincristine sulfate was applied as a positive control. The number of survivors larvae was counted after 24 h incubation at 25 $^{\circ}$ C. The percentage of the lethality of larvae was calculated.

RESULTS AND DISCUSSION

The present study elucidated the biosynthesized of the AgNPs using *A. elongatum* leaves extract and evaluated their biological activities.

The antimicrobial activity of nanoparticles is related to properties such as size, shape, and morphology. Active molecules in the extract, such as polyphenols, reduce metal ions to form nanoparticles. This mechanism describes the synthesis of nanoparticles by the plant extract.

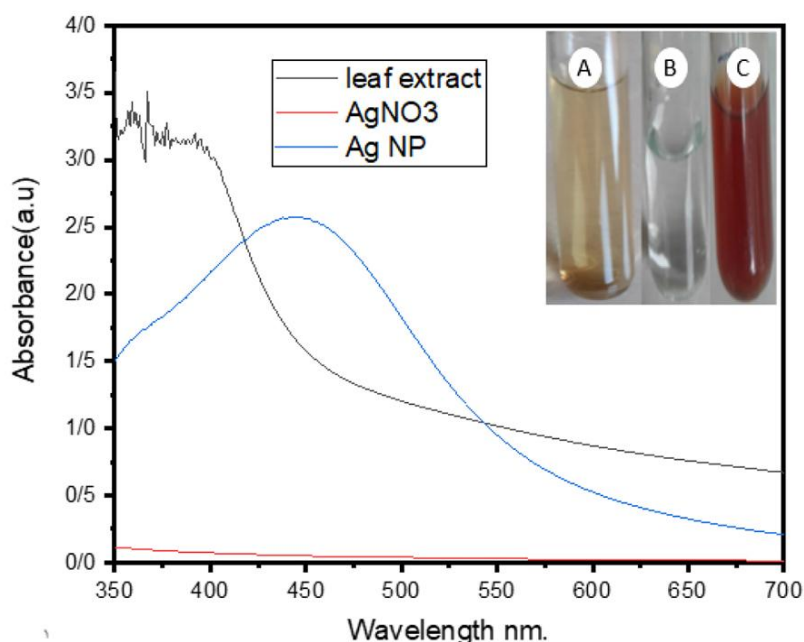


Fig. 1. UV-Vis absorption spectra of the Ag-AgCl nanocomposite, *A. elongatum* leaves extract and $AgNO_3$ solution in 350 – 700 nm wavelength. Color changes of the solution during formation of nanoparticles: (A) extract, (B) silver solution, and (C) silver nanoparticle solution.

M, n, and Ar are the metal ion and the number of groups oxidized and the aromatic ring, respectively [33,34].



UV-Vis spectroscopy

The synthesis of silver nanoparticles was confirmed using the color change of the AgNO₃ solution to dark brown (Fig. 1). The changing color was observed when the surface plasmonic resonance phenomena were excited in silver nanoparticles [35]. In the synthesis AgNPs, the intensity of the change in color of the solution increased during the incubation time.

The synthesis of silver nanoparticles was monitored using the UV-Vis Spectrophotometer at 350–700 nm. The results exhibited a single, strong peak around 433 nm after 48 h, whereas the absorption peak was not observed for the extract of *A. elongatum* and AgNO₃ solution used as control (Fig. 1).

Therefore, this result confirmed that the extract could reduce and stabilize the nanoparticles. The synthesized silver nanoparticles covered with biomolecules are well dispersed in the solution [34]. Similar results showed that the absorption peak of silver nanoparticles was 400-500 nm.

The silver nanoparticle synthesized with *Aegle marmelos*, *Berberis lyceum*, and *Piper nigrum* leaves extract revealed 436, 458, and 460 nm [19,36]. The result of UV-Vis Spectroscopy has to overlap with a previous study by Mehmood et al. (2014).

XRD

The XRD technique determined the structure of crystal AgNPs in the range of 5 - 90° at 2θ angle. Fig. 2b showed several diffraction peaks characteristic of the crystalline nanoparticle at 2θ values of ~ 28°, 33°, 38°, 45°, 47°, 65°, and 78°. The XRD peaks at ~28° and ~33° were attributed to the Cl of AgCl. Also, at 2θ =38.36, it has the highest peak, related to Ag. The average crystalline size of the synthesized AgNPs was 23 nm, estimated by the Scherrer equation.

FT-IR

Phenolic compounds such as gallic acid, benzoic acid, and flavonoids are plant metabolites. The FT-IR spectrum is evaluated to compare the capped biomolecules on the AgNPs, and the organic compounds and functional groups of the leaves extract [37,38].

The absorption peaks of the leaves extract were determined at 3049 cm⁻¹ (stretch O-H), 2925 cm⁻¹(stretch C-H), 1595cm⁻¹ (stretch), 1403cm⁻¹

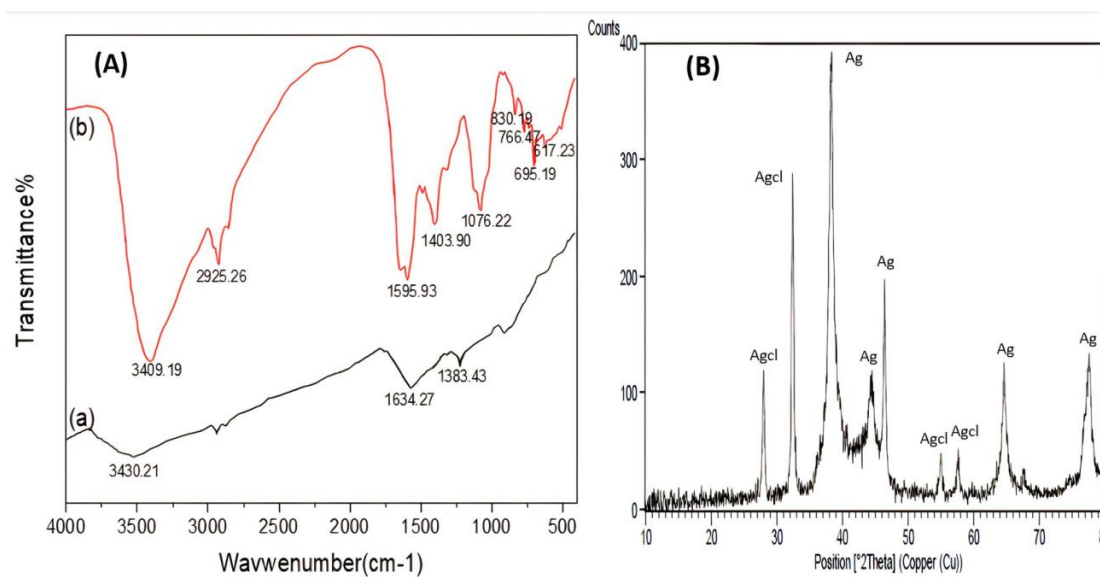


Fig. 2. (A): The FT-IR spectrum of the Ag-AgCl nanocomposite (a) and the extract (b) and (B): XRD pattern of synthesized Ag-AgCl nanocomposite.



(stretch C-H), 1076 cm^{-1} (stretch C-O), and 830 cm^{-1} , 766 cm^{-1} , 695 cm^{-1} , 617 cm^{-1} compounds aromatic ring in the phenolic [38-40].

In contrast, these six peaks are absent in the corresponding silver nanoparticle spectra. However, the peaks around 3430 cm^{-1} and 1634 cm^{-1} and 1383 cm^{-1} were observed in the nanoparticles. The absorption peaks at 3430 cm^{-1} indicate hydroxyl groups assigned to O-H stretching frequency. Also, the bands at 1634 cm^{-1} are commonly related to alkenes [41], and 1383 cm^{-1} ascribed to C-N stretching vibrations of aromatic [42]. The other bands in the FTIR spectrum occurred due to the biomaterials of the extract. They provided stable nanoparticles with the functional groups in this region, responsible for reducing/stabilizing the AgNPs.

Linkages in C-O and C=O functional groups are related to being groups of flavones, terpenoids, and polysaccharides in the plant extract. The biomolecules of the extract have been identified on the surface of AgNPs synthesized from the plant extract [43].

SEM

The SEM micrograph demonstrated that the morphology of the nanoparticles was an almost spherical shape. Furthermore, the size of the nanoparticles was in the range of 32–38 nm, and the average diameter of 6.45 nm (Fig. 3A and Fig. 3B).

In similar study, Sahoo et al. reported spherical silver nanoparticles synthesized using *Punica granatum* L. with a size of 40-80 nm [43].

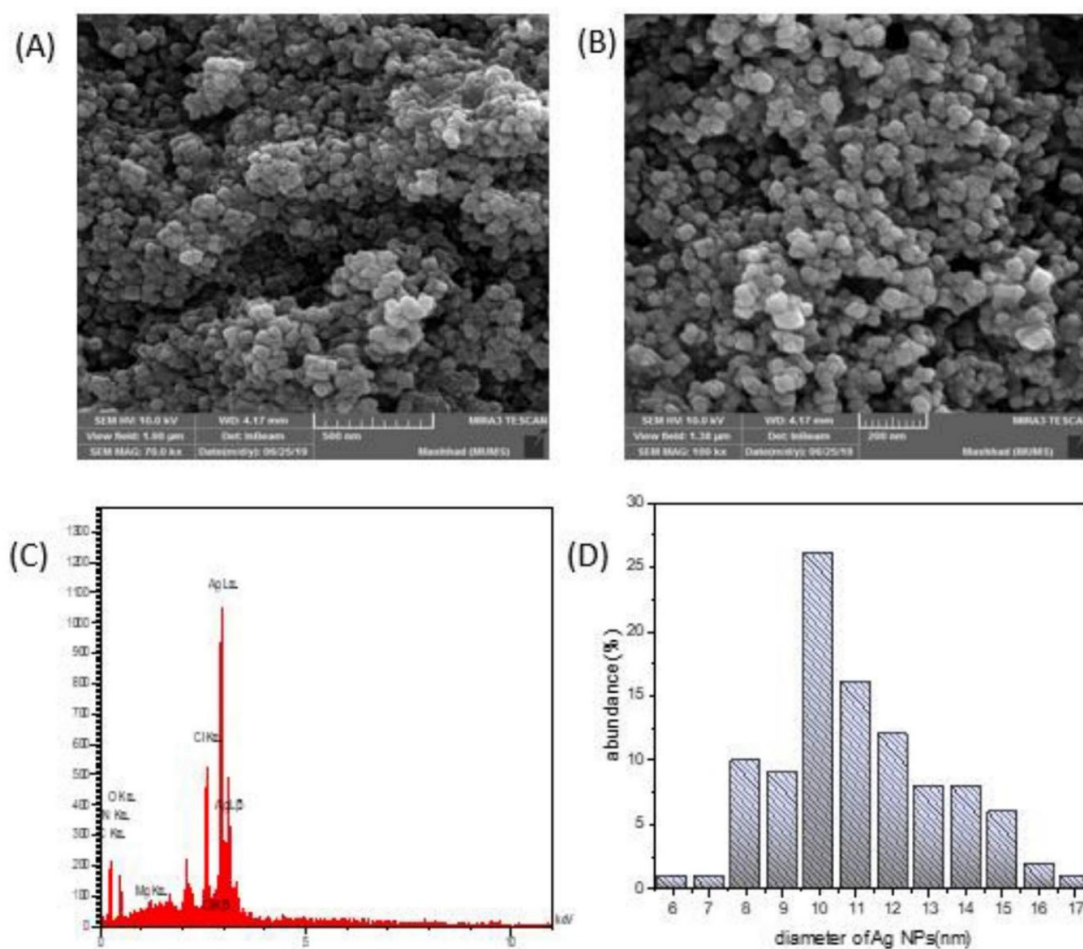


Fig. 3. SEM (A and B), EDX spectra of the Ag-AgCl nanocomposite (C), and histogram of the size distribution of the nanoparticles (D).

The histogram of the size distribution of nanoparticles was obtained by counting 100 particles in different regions and is shown in Fig. 3D.

EDX analysis determined the presence of the silver element. Moreover, other signals were detected in the EDX spectrum, confirming the present elements like Cl, O, N, Mg, and C. It suggested that the element peaks such as Cl, O, N, and C were obtained from plant extract [44].

Antibacterial activity of AgNPs

Silver nanoparticles could be applied against various bacterial pathogens that are antibiotics resistant. The antimicrobial properties of silver nanoparticles depend on size, pH, ionic strength, and capping agent [45]. In this study, the antimicrobial effect of AgNPs was investigated against the sixteen human pathogenic strains using the broth microdilution method. The MIC values are summarized in Table 1.

The nanoparticles exhibited an antibacterial effect on all the tested strains, with MIC and MBC values in the range of $>2 \pm 0.00$ to 0.0625 ± 0.00 and $2 > \pm 0.00$ to 0.125 ± 0.00 , respectively.

Kim et al. reported the antibacterial activity of silver nanoparticles against *E.coli* and *S.aureus*, which confirmed our results [46]. Moodley et al. synthesized AgNPs from *moringa aleifera* leaf extract and evaluated their antibacterial potential against different bacteria. The MIC values against *K.pneumoniae*, *P.aeruginosa*, and *S.aureus* obtained 25 $\mu\text{g/ml}$, and MIC against *E. coli* and *E. faecalis* was 12.5 $\mu\text{g/ml}$. This study recorded lower antibacterial activity than ours [5]. In another study, AgNPs showed antibacterial effects against *E.coli* and methicillin-resistant *S.aureus* with MIC 1.2 $\mu\text{g/ml}$ and 0.25 $\mu\text{g/ml}$, respectively [47]. However, silver nanoparticles join the cell membrane, penetrate the bacteria, and lead to protein denaturation [48]. Antibacterial activity

depends on the different concentrations of silver nanoparticles. Further, it has been shown that smaller nanoparticles have more antibacterial activity [49]. Yousefzadi et al. investigated biosynthesis AgNPs using green alga *Enteromorpha flexuosa* and the antibacterial potential of AgNPs. Their results indicated that in MBC, the value of *S. epidermidis* was 12.5 $\mu\text{g/ml}$ and MBC of *S. cerevisiae*, *S.aureus*, and *B. subtilis* was 50 $\mu\text{g/ml}$ [50]. A previous study showed that AgNPs synthesized using *Uritica dioica* ethyl acetate extract have high antimicrobial activity and can be used as an alternative to antibiotics (Binsalah et al. 2022).

Cytotoxicity activity of AgNPs

The cytotoxicity effect of the silver nanoparticles was determined using the BSL assay. The cytotoxicity potential of the AgNPs was evaluated at concentrations 300, 250, 200, 150, 100, and 50 $\mu\text{g/ml}$ and compared to vincristine sulfate (VS) as a positive control. All the samples showed good brine shrimp larvicidal effect. The AgNPs have killed (90%) brine shrimp larvae at the highest concentration (300 $\mu\text{g/ml}$). Furthermore, minimum mortalities (20%) were indicated at 50 $\mu\text{g/ml}$ concentration. The results showed that the LC_{50} of Ag nanoparticles and vincristine sulfate were 120 ± 0.00 and $0.751 \pm 0.008 \mu\text{g/ml}$, respectively (Fig. 4).

The previous research determined that toxicity against *A. salina* included inactive ($LC_{50} > 1000 \mu\text{g/ml}$), weakly toxic ($LC_{50} < 500-1000 \mu\text{g/ml}$), moderately toxic ($LC_{50} 100-500 \mu\text{g/ml}$), and highly toxic ($LC_{50} < \mu\text{g/ml}$) [51]. According to these reports, the AgNPs synthesized using *A. elongatum* have moderately brine shrimp larvicidal activity ($LC_{50} 120 \pm 0.00$). This study is comparable to studies carried out by other researchers. Patil Shrinivas et al. reported the cytotoxicity activity of AgNPs synthesized from *Lantana camara* L. leaves using brine shrimp lethality assay with $LC_{50} 514.50 \mu\text{g/ml}$

Table.1. Determination of)MIC mg/ml, and MBC mg/ml(of the silver nanoparticle against human pathogenic strains.

Bacterial	<i>E.coli</i> (4221)	<i>E.coli</i> (3056)	<i>E.coli</i> (726)	<i>E.coli</i> (4701)	<i>E.coli</i> (4745)	<i>E.coli</i> (2422)	<i>E.coli</i> (4469)	<i>K.pnu monia</i> (14)	<i>E.coli</i> (228)	<i>S.aureus</i> (48629)	<i>E.coli</i> (572)	<i>E.coli</i> (5149)	<i>E.coli</i> (4828)	<i>E.coli</i> (159)	<i>E.coli</i> (3069)	<i>E.coli</i> (885)
MIC	0.25	0.5	0.25	0.25	0.25	0.25	0.125	0.125	0.25	0.0312	0.25	0.25	0.125	0.0625	0.125	0.125
MBC	0.25	0.5	0.25	0.25	0.5	2>	0.25	0.125	2>	2>	0.25	2>	0.25	0.25	0.125	0.125

ml [52]. According to the findings of Vijayan et al., AgNPs synthesized from seaweed had a cytotoxicity effect (LC_{50} 88.914±5.04) using assay [53]. Moreover, according to the results of the BSL test, synthesized nanoparticles using extracts of *Agave Americana*, *Mentha spicata*, and *Mangifera*

indica have good cytotoxicity.

Anti-biofilm

One of the major causes of nosocomial infections is biofilm formation by *E.coli*. In this study, biofilm inhibition potentials of the AgNPs

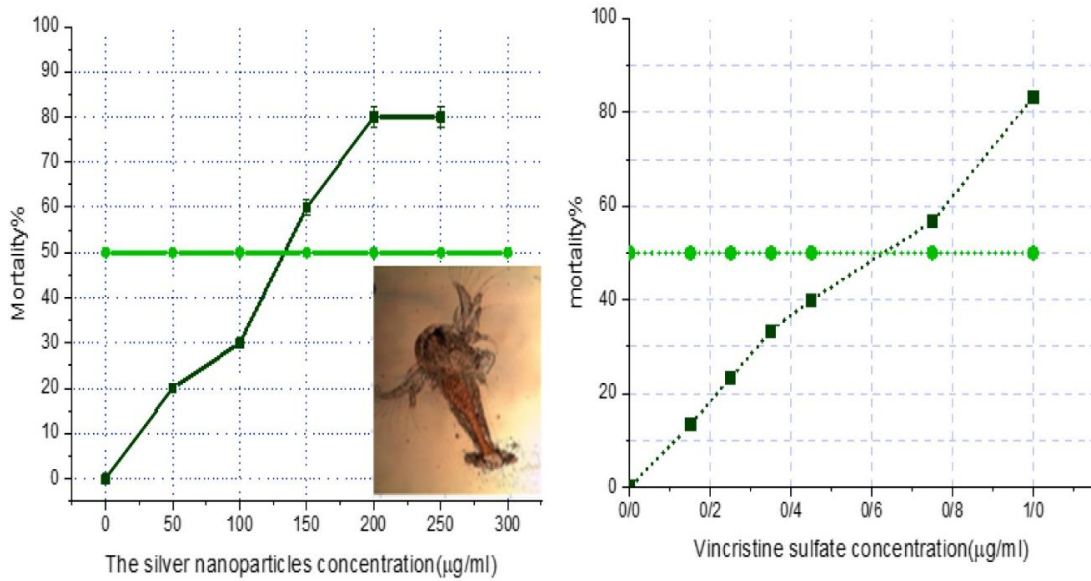


Fig. 4. The cytotoxicity effect of Ag-AgCl nanocomposite (A) and vincristine sulfate (B) after 24h.

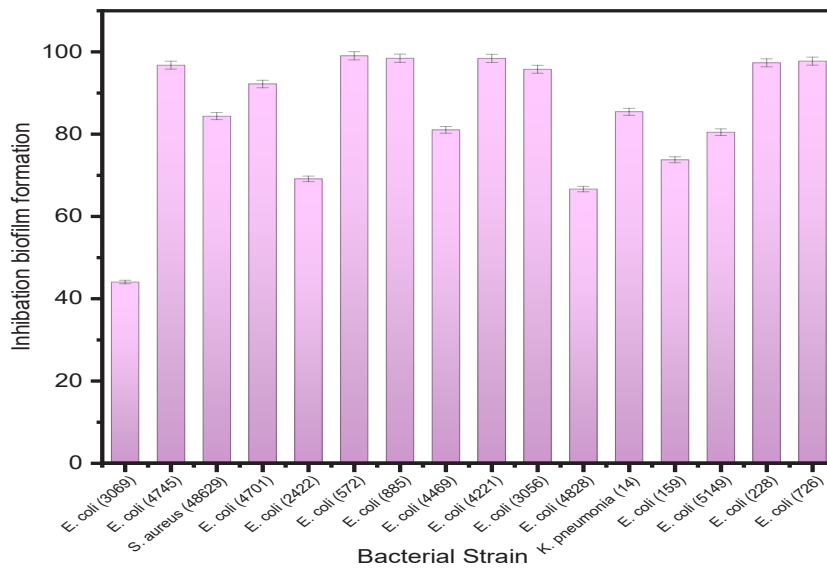


Fig. 5. Anti-biofilm activity of Ag-AgCl nanocomposite synthesized using leaves extract *A. elongatum*.

were evaluated against sixteen strains of the human uropathogenic *E.coli*, *S.aureus*, and *K.pneumoniae*. These strains were able to form biofilms. As result, the AgNPs (1 µg/ml) inhibited over 90% biofilm formation.

The effect of AgNPs against the formation of biofilm was reported in some studies [53-55]. AgNPs synthesized using leaves extract of *Convolvulus arvensis* exhibited biofilm degrading activity against both *S.aureus* and *Paeruginosa* [56]. In another study, silver nanoparticles synthesized from garlic extract showed a robust anti-biofilm effect against *S.aureus* [57]. A similar study has been previously reported that AgNPs could inactivate the biofilm formation of *S. aureus* strains [58]. Sahoo et al. reported that AgNP synthesized using *Punica granatum* L. was a biofilm inhibitor against *S. aureus* [59]. Further, another researcher has reported that AgNP made from fruit extract of *Chrysophyllum albidum* has a high biofilm effect on methicillin-resistant *S.aureus* [60].

The finding of this study showed that the silver nanoparticles were successfully synthesized by *A.elongatum* leaves extract. The formation of AgNPs was confirmed by UV-visible spectroscopy, XRD, FTIR, SEM, and EDX analysis. The analysis showed that the AgNPs had spherical morphology. The biological activity of the AgNPs was evaluated using anti-biofilm, anticancer, and antimicrobial activity. Brine shrimp lethality (BSL) assay was applied to investigate the anticancer activity. The nanoparticles exhibited good cytotoxicity activity. Furthermore, the synthesized AgNPs indicated powerful antibacterial and anti-biofilm effects against human uropathogenic. These results suggested that the silver nanoparticles could be used as antimicrobial, anticancer, and anti-biofilm against pathogenic bacteria. However, the antibacterial effect of the AgNPs could be due to the interaction between the cell membrane bacteria and AgNPs.

CONCLUSION

In this study, a robust antimicrobial and cytotoxic silver nanoparticle was produced using a novel, simple and environmentally friendly pathway with leaves extract of *A.elongatum* collected from Kohgiluyeh and Boyer-Ahmad province, Iran. The results showed that the nanoparticles have an antibacterial effect on human pathogenic strains, including *E.coli*, *S. aureus*, and *K.*

pneumonia, in Qom Hospital, Iran. Moreover, the silver nanoparticles inhibit the biofilm of uropathogenic bacteria. Based on the results, the silver nanoparticles can be a good candidate for treating urinary infections caused by a biofilm of uropathogenic bacteria.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

REFERENCES

1. Khodashenas B, Ghorbani HR. Synthesis of silver nanoparticles with different shapes. *Arabian Journal of Chemistry*. 2019;12(8):1823-1838.
2. Rafique M, Sadaf I, Tahir MB, Rafique MS, Nabi G, Iqbal T, et al. Novel and facile synthesis of silver nanoparticles using *Albizia procera* leaf extract for dye degradation and antibacterial applications. *Materials Science and Engineering: C*. 2019;99:1313-1324.
3. Jana U, Mohanty AK, Pal SL, Manna PK, Mohanta GP. Felodipine loaded PLGA nanoparticles: preparation, physicochemical characterization and in vivo toxicity study. *Nano Convergence*. 2014;1(1).
4. Fahimirad S, Ajallouei F, Ghorbanpour M. Synthesis and therapeutic potential of silver nanomaterials derived from plant extracts. *Ecotoxicology and Environmental Safety*. 2019;168:260-278.
5. Moodley JS, Krishna SBN, Pillay K, Sershen, Govender P. Green synthesis of silver nanoparticles from *Moringa oleifera* leaf extracts and its antimicrobial potential. *Advances in Natural Sciences: Nanoscience and Nanotechnology*. 2018;9(1):015011.
6. Rai M, Yadav A, Gade A. Silver nanoparticles as a new generation of antimicrobials. *Biotechnol Adv*. 2009;27(1):76-83.
7. Vidhu VK, Aromal SA, Philip D. Green synthesis of silver nanoparticles using *Macrotyloma uniflorum*. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*. 2011;83(1):392-397.
8. Crooks RM, Lemon BI, Sun L, Yeung LK, Zhao M. Dendrimer-Encapsulated Metals and Semiconductors: Synthesis, Characterization, and Applications. *Topics in Current Chemistry*: Springer Berlin Heidelberg; 2000. p. 81-135.
9. Gittins DI, Bethell D, Schiffrin DJ, Nichols RJ. A nanometre-scale electronic switch consisting of a metal cluster and redox-addressable groups. *Nature*. 2000;408(6808):67-69.
10. Sengupta S, Eavarone D, Capila I, Zhao G, Watson N, Kiziltepe T, et al. Temporal targeting of tumour cells and neovasculature with a nanoscale delivery system. *Nature*. 2005;436(7050):568-572.
11. Jorge de Souza TA, Rosa Souza LR, Franchi LP. Silver nanoparticles: An integrated view of green synthesis methods, transformation in the environment, and toxicity. *Ecotoxicology and Environmental Safety*. 2019;171:691-700.
12. Abou El-Nour KMM, Eftaiha Aa, Al-Warthan A, Ammar RAA. Synthesis and applications of silver nanoparticles. *Arabian Journal of Chemistry*. 2010;3(3):135-140.
13. Rolim WR, Pelegrino MT, de Araújo Lima B, Ferraz LS, Costa FN, Bernardes JS, et al. Green tea extract mediated

- biogenic synthesis of silver nanoparticles: Characterization, cytotoxicity evaluation and antibacterial activity. *Appl Surf Sci.* 2019;463:66-74.
14. Jini D, Sharmila S. Green synthesis of silver nanoparticles from *Allium cepa* and its in vitro antidiabetic activity. *Materials Today: Proceedings.* 2020;22:432-438.
 15. Alam MF, Laskar AA, Zubair M, Baig U, Younus H. Immobilization of yeast alcohol dehydrogenase on polyaniline coated silver nanoparticles formed by green synthesis. *J Mol Catal B: Enzym.* 2015;119:78-84.
 16. Green synthesis and characterization of iron oxide nanoparticles using *Coriandrum sativum* L. leaf extract. *Indian Journal of Biochemistry and Biophysics.* 2022.
 17. Ahmed S, Ahmad M, Swami BL, Ikram S. A review on plants extract mediated synthesis of silver nanoparticles for antimicrobial applications: A green expertise. *Journal of Advanced Research.* 2016;7(1):17-28.
 18. S.S.D, M.B M, M.N SK, Golla R, P RK, S D, et al. Antimicrobial, anticoagulant and antiplatelet activities of green synthesized silver nanoparticles using *Selaginella* (Sanjeevini) plant extract. *Int J Biol Macromol.* 2019;131:787-797.
 19. Devi M, Devi S, Sharma V, Rana N, Bhatia RK, Bhatt AK. Green synthesis of silver nanoparticles using methanolic fruit extract of *Aegle marmelos* and their antimicrobial potential against human bacterial pathogens. *Journal of Traditional and Complementary Medicine.* 2020;10(2):158-165.
 20. Femi-Adepoju AG, Dada AO, Otun KO, Adepoju AO, Fatoba OP. Green synthesis of silver nanoparticles using terrestrial fern (*Gleichenia Pectinata* (Willd.) C. Presl.): characterization and antimicrobial studies. *Heliyon.* 2019;5(4):e01543.
 21. Ranozek-Soliwoda K, Tomaszewska E, Matek K, Celichowski G, Orłowski P, Krzyzowska M, et al. The synthesis of monodisperse silver nanoparticles with plant extracts. *Colloids Surf B Biointerfaces.* 2019;177:19-24.
 22. Aksu Demirezen D, Yildiz YŞ, Yilmaz Ş, Demirezen Yilmaz D. Green synthesis and characterization of iron oxide nanoparticles using *Ficus carica* (common fig) dried fruit extract. *Journal of Bioscience and Bioengineering.* 2019;127(2):241-245.
 23. Kumar Sur U, Ankamwar B, Karmakar S, Halder A, Das P. Green synthesis of Silver nanoparticles using the plant extract of *Shikakai* and *Reetha*. *Materials Today: Proceedings.* 2018;5(1):2321-2329.
 24. Ali ZA, Yahya R, Sekaran SD, Puteh R. Green Synthesis of Silver Nanoparticles Using Apple Extract and Its Antibacterial Properties. *Advances in Materials Science and Engineering.* 2016;2016:1-6.
 25. Hemmati S, Rashtiani A, Zangeneh MM, Mohammadi P, Zangeneh A, Veisi H. Green synthesis and characterization of silver nanoparticles using *Fritillaria* flower extract and their antibacterial activity against some human pathogens. *Polyhedron.* 2019;158:8-14.
 26. Deshmukh SP, Patil SM, Mullani SB, Delekar SD. Silver nanoparticles as an effective disinfectant: A review. *Materials Science and Engineering: C.* 2019;97:954-965.
 27. Soares MRPS, Corrêa RO, Stroppa PHF, Marques FC, Andrade GFS, Corrêa CC, et al. Biosynthesis of silver nanoparticles using *Caesalpinia ferrea* (Tul.) Martius extract: physicochemical characterization, antifungal activity and cytotoxicity. *PeerJ.* 2018;6:e4361.
 28. Sharma VK, Yngard RA, Lin Y. Silver nanoparticles: Green synthesis and their antimicrobial activities. *Advances in Colloid and Interface Science.* 2009;145(1-2):83-96.
 29. Liu J-f, Yu S-j, Yin Y-g, Chao J-b. Methods for separation, identification, characterization and quantification of silver nanoparticles. *TrAC, Trends Anal Chem.* 2012;33:95-106.
 30. Edison TNJI, Lee YR, Sethuraman MG. Green synthesis of silver nanoparticles using *Terminalia cuneata* and its catalytic action in reduction of direct yellow-12 dye. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy.* 2016;161:122-129.
 31. Martínez-Gutiérrez F, Thi EP, Silverman JM, de Oliveira CC, Svensson SL, Hoek AV, et al. Antibacterial activity, inflammatory response, coagulation and cytotoxicity effects of silver nanoparticles. *Nanomed Nanotechnol Biol Med.* 2012;8(3):328-336.
 32. Obeizi Z, Benbouzid H, Ouchenane S, Yilmaz D, Culha M, Bououdina M. Biosynthesis of Zinc oxide nanoparticles from essential oil of *Eucalyptus globulus* with antimicrobial and anti-biofilm activities. *Materials Today Communications.* 2020;25:101553.
 33. Chokshi K, Pancha I, Ghosh T, Paliwal C, Maurya R, Ghosh A, et al. Green synthesis, characterization and antioxidant potential of silver nanoparticles biosynthesized from de-oiled biomass of thermotolerant oleaginous microalgae *Acutodesmus dimorphus*. *RSC Advances.* 2016;6(76):72269-72274.
 34. Arya A, Mishra V, Chundawat TS. Green synthesis of silver nanoparticles from green algae (*Botryococcus braunii*) and its catalytic behavior for the synthesis of benzimidazoles. *Chemical Data Collections.* 2019;20:100190.
 35. Bindhu MR, Umadevi M. Synthesis of monodispersed silver nanoparticles using *Hibiscus cannabinus* leaf extract and its antimicrobial activity. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy.* 2013;101:184-190.
 36. Mehmood A, Murtaza G, Bhatti TM, Kausar R. Environmentally Friendly Synthesis of Silver Nanoparticles Using *Berberis lycium* Leaf Extract and Their Antibacterial Efficacy. *Acta Metallurgica Sinica (English Letters).* 2014;27(1):75-80.
 37. Paulkumar K, Gnanajobitha G, Vanaja M, Rajeshkumar S, Malarkodi C, Pandian K, et al. Piper nigrum Leaf and Stem Assisted Green Synthesis of Silver Nanoparticles and Evaluation of Its Antibacterial Activity Against Agricultural Plant Pathogens. *The Scientific World Journal.* 2014;2014:1-9.
 38. de Jesús Ruíz-Baltazar Á, Reyes-López SY, Larrañaga D, Estévez M, Pérez R. Green synthesis of silver nanoparticles using a *Melissa officinalis* leaf extract with antibacterial properties. *Results in Physics.* 2017;7:2639-2643.
 39. Kumari RM, Thapa N, Gupta N, Kumar A, Nimesh S. Antibacterial and photocatalytic degradation efficacy of silver nanoparticles biosynthesized using *Cordia dichotoma* leaf extract. *Advances in Natural Sciences: Nanoscience and Nanotechnology.* 2016;7(4):045009.
 40. Pugazhendhi A, Prabakar D, Jacob JM, Karuppusamy I, Saratale RG. Synthesis and characterization of silver nanoparticles using *Gelidium amansii* and its antimicrobial property against various pathogenic bacteria. *Microb Pathog.* 2018;114:41-45.
 41. Sigamoney M, Shaik S, Govender P, Krishna SBN, Sershen. African leafy vegetables as bio-factories for silver nanoparticles: A case study on *Amaranthus dubius* C Mart. *Ex Thell. S Afr J Bot.* 2016;103:230-240.
 42. Shamel K, Bin Ahmad M, Jaffar Al-Mulla EA, Ibrahim NA, Shabanzadeh P, Rustaiyan A, et al. Green Biosynthesis of Silver Nanoparticles Using *Callicarpa maingayi* Stem Bark Extraction. *Molecules.* 2012;17(7):8506-8517.
 43. Prasannaraj G, Venkatachalam P. Green engineering of

- biomolecule-coated metallic silver nanoparticles and their potential cytotoxic activity against cancer cell lines. *Advances in Natural Sciences: Nanoscience and Nanotechnology*. 2017;8(2):025001.
44. Hernández-Morales L, Espinoza-Gómez H, Flores-López LZ, Sotelo-Barrera EL, Núñez-Rivera A, Cadena-Nava RD, et al. Study of the green synthesis of silver nanoparticles using a natural extract of dark or white *Salvia hispanica* L. seeds and their antibacterial application. *Appl Surf Sci*. 2019;489:952-961.
 45. Palencia MS, Berrio ME, Palencia SL. Effect of Capping Agent and Diffusivity of Different Silver Nanoparticles on Their Antibacterial Properties. *Journal of Nanoscience and Nanotechnology*. 2017;17(8):5197-5204.
 46. Kim JS, Kuk E, Yu KN, Kim J-H, Park SJ, Lee HJ, et al. Corrigendum to "Antimicrobial effects of silver nanoparticles" [Nanomed Nanotechnol Biol Med. 2007;1:95-101]. *Nanomed Nanotechnol Biol Med*. 2014;10(5):e1119.
 47. Ortiz C, Torres R, Paredes D. Synthesis, characterization, and evaluation of antibacterial effect of Ag nanoparticles against *Escherichia coli* O157:H7 and methicillin-resistant *Staphylococcus aureus* (MRSA). *International Journal of Nanomedicine*. 2014:1717.
 48. Sorbiun M, Shayegan Mehr E, Ramazani A, Taghavi Fardood S. Green Synthesis of Zinc Oxide and Copper Oxide Nanoparticles Using Aqueous Extract of Oak Fruit Hull (Jaft) and Comparing Their Photocatalytic Degradation of Basic Violet 3. *International Journal of Environmental Research*. 2018;12(1):29-37.
 49. Baker C, Pradhan A, Pakstis L, Pochan D, Shah SI. Synthesis and Antibacterial Properties of Silver Nanoparticles. *Journal of Nanoscience and Nanotechnology*. 2005;5(2):244-249.
 50. Yousefzadi M, Rahimi Z, Ghafari V. The green synthesis, characterization and antimicrobial activities of silver nanoparticles synthesized from green alga *Enteromorpha flexuosa* (wulfen) J. *Agardh. Mater Lett*. 2014;137:1-4.
 51. Rajabi S, Ramazani A, Hamidi M, Naji T. *Artemia salina* as a model organism in toxicity assessment of nanoparticles. *DARU Journal of Pharmaceutical Sciences*. 2015;23(1).
 52. P PS, T KS. Antioxidant, antibacterial and cytotoxic potential of silver nanoparticles synthesized using terpenes rich extract of *Lantana camara* L. leaves. *Biochemistry and Biophysics Reports*. 2017;10:76-81.
 53. Vijayan SR, Santhiyagu P, Singamuthu M, Kumari Ahila N, Jayaraman R, Ethiraj K. Synthesis and Characterization of Silver and Gold Nanoparticles Using Aqueous Extract of Seaweed, *Turbinaria conoides*, and Their Antimicrofouling Activity. *The Scientific World Journal*. 2014;2014:1-10.
 54. Rajivgandhi G, Maruthupandy M, Muneeswaran T, Anand M, Quero F, Manoharan N, et al. Biosynthesized silver nanoparticles for inhibition of antibacterial resistance and biofilm formation of methicillin-resistant coagulase negative *Staphylococci*. *Bioorg Chem*. 2019;89:103008.
 55. Liang Z, Qi Y, Guo S, Hao K, Zhao M, Guo N. Effect of AgWPA nanoparticles on the inhibition of *Staphylococcus aureus* growth in biofilms. *Food Control*. 2019;100:240-246.
 56. Hamedi S, Shojaosadati SA, Mohammadi A. Evaluation of the catalytic, antibacterial and anti-biofilm activities of the *Convolvulus arvensis* extract functionalized silver nanoparticles. *J Photochem Photobiol B: Biol*. 2017;167:36-44.
 57. Girish VM, Liang H, Aguilan JT, Nosanchuk JD, Friedman JM, Nacharaju P. Anti-biofilm activity of garlic extract loaded nanoparticles. *Nanomed Nanotechnol Biol Med*. 2019;20:102009.
 58. Khalid HF, Tehseen B, Sarwar Y, Hussain SZ, Khan WS, Raza ZA, et al. Biosurfactant coated silver and iron oxide nanoparticles with enhanced anti-biofilm and anti-adhesive properties. *J Hazard Mater*. 2019;364:441-448.
 59. Sahoo B, Panigrahi LL, Das RP, Pradhan AK, Arakha M. Biogenic Synthesis of Silver Nanoparticle from *Punica granatum* L. and Evaluation of Its Antioxidant, Antimicrobial and Anti-biofilm Activity. *Journal of Inorganic and Organometallic Polymers and Materials*. 2022;32(11):4250-4259.
 60. Ankudze B, Neglo D. Green synthesis of silver nanoparticles from peel extract of *Chrysophyllum albidum* fruit and their antimicrobial synergistic potentials and biofilm inhibition properties. *BioMetals*. 2022;36(4):865-876.