Original Article

Trends in Pharmaceutical Sciences and Technologies 2026: 12(2):177-188.

Green Synthesis of Silver Using *Eucalyptus camaldulensis* Leaf Extract and Evaluation of its Antibacterial and Antifungal Activities

Behrooz Mosallanejad[1*];MSc, , Raziey Parastan[1];Ph.D, Masumeh Ranjbar[1];MSc, Saeede Safajoo[1];MSc, Fateme Darooghe[1];MSc, Abolfazl Rahmaneian[1];Ph.D, Ahmad Ahmadi Daryakenari[2];Ph.D

[1]Department of Food and Drug, Jahrom University of Medical Sciences, Jahrom, Iran
[2]Department of Nanotechnology, Faculty of Engineering, University of Guilan, Rasht, Iran

Abstract

Silver as a noble metal has played an important role in the treatment of infectious diseases. Various techniques are adopted in order to synthesize silver, the most important of which are physical and chemical methods. Although these approaches are much widely used, they are economically expensive and utilize toxic chemicals. To overcome these issues, green synthesis is put forward since it is cost-effective and environmentally friendly. This research focuses on green synthesis of silver using *Eucalyptus camaldulensis* (*E. camaldulensis*) leaf extract. For this purpose, silver nitrate was employed as the source of silver ions and *E. camaldulensis* leaves extract was utilized in order to reduce Ag^{+} ions into Ag^{0}. Then, the resulting Ag powder was structurally characterized by means of different techniques. Ultimately, the antibacterial and antifungal properties of green-synthesized Ag were examined against *Escherichia coli* (*E. coli*) and *Staphylococcus aureus* (*S. aureus*) bacteria and *Candida albicans* (*C. albicans*) and *Aspergillus niger* (*A. niger*) fungi using different antimicrobial assays. In accordance with XRD results, the resulting powder predominantly included silver. In addition to FTIR, the presence of reducing agents of phytochemical compounds were confirmed by total phenolic content (TPC) and total flavonoid content (TFC) measurements. Based on antimicrobial evaluations, the synthesized Ag revealed antibacterial and antifungal activities against *E. coli* and *S. aureus* bacteria and *C. albicans* and *A. niger* fungi. In accordance with our findings, the proposed approach in this study could suggest a facile, green, and eco-friendly method for synthesizing Ag possessing antibacterial and antifungal activities.

Keywords: Silver, *Eucalyptus camaldulensis*, *Escherichia coli*, *Candida albicans*, Antibacterial, Antifungal.

Please cite this article as: Mosallanejad B, , Parastan R, Ranjbar M, Safajoo S, Darooghe F, Rahmaneian A, *et al*. Green synthesis of silver using *Eucalyptus camaldulensis* leaf extract and evaluation of its antibacterial and antifungal activities. Trends in Pharmaceutical Sciences and Technologies. 2026;12(2):177-188. doi: 10.30476/tips.2026.111261.1356

Copyright: ©Trends in Pharmaceutical Sciences and Technologies. This is an open-access article distributed under the terms of the Creative Commons Attribution-NoDerivatives 4.0 International License. This license allows reusers to copy and distribute the material in any medium or format in unadapted form only, and only so long as attribution is given to the creator. The license allows for commercial use.

1. Introduction

Infectious diseases have become one of the main reasons behind today's death worldwide, some of which appear during healthcare in hospitals and other medical centers. Some of this kind of diseases are caused by drug-resistant bacteria, which are among the most serious and deadly types of infectious diseases. The reason behind it is that drug-resistant bacteria are able to diminish patients' susceptibility to antimicrobial drugs and subsequently, increase infections (1-3).

To combat drug-resistant bacteria, transition metals are an appropriate option, whose therapeutic properties backs to medi-

Corresponding Author: Behrooz Mosallanejad; Department of Food and Drug, Jahrom University of Medical Sciences, Jahrom, Iran
E-mail: bmosallanejad@aut.ac.ir

Received: 21/10/2025; Accepted: 01/03/2026

eval period. Different types of transition metals are available, the most important of which are silver, mercury, gold, zinc, and copper (4, 5). Silver (Ag) as one of the most renowned transition metals is widely utilized in varied fields, from biomedicine to food industry, agriculture, and the environment. In the field of biomedicine, silver has revealed immense potential toward growth controlling or destroying of pathogenic microorganisms, including bacteria and viruses. Silver, in accordance with literature, is a toxic compound to disease-causing organisms, by which hinders their growth through various mechanisms, for instance disrupting cell membranes, impeding enzyme activity, and damaging their DNA (6-8). In addition to these antimicrobial properties, silver is a useful element in treatment of cancer, healing of wound and burn injuries, fabrication of coatings for implants, drug delivery, biosensors, and bioimaging (9).

For the synthesis of silver, different techniques are proposed, among which chemical and physical methods are the most widely used. In spite of their high diversity, chemical and physical methods suffer from several disadvantages. Physical methods require sophisticated equipment, which not only poses challenges for large-scale production of silver, but also results in generation of a highly-cost product (9). In contrast, chemical methods are not biocompatible or environmentally friendly because of using toxic chemicals, which could generate hazardous by-products during the manufacturing process (10, 11). To address these issues, green synthesis method is a suited alternative to chemical and physical methods, in which plant extracts are adopted. Due to containing phytochemical compounds, including phenolic acids, flavonoids, amines, and ketones, plant extracts are capable of reducing silver ions (Ag^{+}) to neutral silver (Ag^{0}) through the reduction process (11, 12).

In this regard and based on Mohammed's study (13), Ag nanoparticles were synthesized using *Eucalyptus camaldulensis* (*E. camaldulensis*) extract due to having reducing and stabilizing agents of flavonoid and terpenoid. The results obtained from agar well diffusion assay revealed that green-synthesized Ag nanoparticles possess potential antibacterial activity against *Pseudomonas aeruginosa* and *Escherichia coli* (*E. coli*) as Gram-negative bacteria and *Staphylococcus aureus* (*S. aureus*) and *Bacillus subtilis* as Gram-positive bacteria. In another study (14), Ag nanoparticles were prepared using aqueous extract of *E. camaldulensis* leaves, green tea, and black tea because of having high amount of antioxidant phenolic. The Ag nanoparticles prepared by means of natural extracts demonstrated inhibitory effects against various Gram-negative and Gram-positive pathogenic bacteria.

In spite of some research performed on antibacterial activity of Ag prepared using *E. camaldulensis* extract against *E. coli* and *S. aureus*, negligible effort has been made in order to assess their antifungal properties against *Candida albicans* (*C. albicans*) and *Aspergillus niger* (*A. niger*). Hence, in the present study, silver is synthesized using a green and environmentally friendly method in which *E. camaldulensis* leaves extract is employed as reducing agent. Then, various characterization tests, including X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), and scanning electron microscopy (SEM), are adopted in order to characterize its structure. Finally, the antibacterial and antifungal properties of green-synthesized silver are evaluated against *E. coli* and *S. aureus* bacteria and *C. albicans* and *A. niger* fungi using different antimicrobial assays.

2. Materials and Methods

2.1. Chemicals

The chemicals used in this study were of analytical grade and employed without further purification. Silver nitrate ($AgNO_3$, Merck, Germany) was adopted as the source of silver. The solvent utilized for preparing aqueous solutions was deionized water.

2.2. E. camaldulensis leaves extract preparation and evaluation

Fresh leaves of *E. camaldulensis* were collected from a local urban tree in Jahrom County, Fars Province, Iran (coordinates: 28°29′55.1″ N, 53°33′46.9″ E). The collected leaves were then washed with deionized water several times, followed by drying under sunlight for 24 h. The dried *E. camaldulensis*

leaves were completely ground into powder. Afterward, 10 g of the fine powder was mixed with 100 mL of deionized water, followed by boiling it on a heater along with continuous stirring. Ultimately, the mixture was filtered by means of a filter paper to separate the extract. The resultant dark yellow extract was stored at 4 °C for further use.

In order to quantitatively assess the phytochemical compounds present in *E. camaldulensis* leaves extract, the total phenolic content (TPC) and total flavonoid content (TFC) parameters were measured. In this regard, TPC was quantified following a colorimetric method using Folin-Ciocalteu reagent. The TPC value was reported as mg of gallic acid equivalents per gram of extract (mg GAE $g^{-1}_{extract}$) (15). For determination of TFC of the extract, the aluminum chloride ($AlCl_3$) colorimetric assay was adopted. The TFC results were expressed as mg of quercetin equivalents per gram of extract (mg QE $g^{-1}_{extract}$) (16).

2.3. Green synthesis of silver

In order to synthesis silver, 45 mL of *E. camaldulensis* leaves extract was added dropwise into 100 mL of colorless aqueous AgNO3 solution (0.05 mol L^{-1}), followed by stirring continuously. Over time, the color of the extract changed from dark yellow to dark brown, indicating the formation of silver as the literature mentioned. Finally and to separate the resultant silver, the final solution was centrifuged at 9000 rpm for 30 min.

2.4. Characterization analyses

The crystalline structure of the synthesized silver was analyzed by means of a High Performance XRD Diffractometer-Explorer (GNR Company, Italy) using Cu Kα radiation at a wavelength of 0.15418 nm. To investigate the functional groups present in prepared powder, FTIR analysis was performed (Bruker Alpha model). The morphology of the silver was studied using a Philips XL30 scanning electron microscope.

2.5. Antibacterial and antifungal assays

To evaluate antibacterial and antifungal properties of the prepared silver, disk diffusion test was conducted on *E. coli* (ATCC 7839) and *S. aureus* (ATCC 29213) bacteria and *C. albicans* (ATCC 10231) and *A. niger* fungi. The concentration of green-synthesized silver used for each measurement was 100 mg L-1. Sterilized distilled water was assigned as the negative control (C^-), whose amount employed for each disk diffusion test was 100 µL.

For the positive control (C^+), 50 µg of chloramphenicol was used for the assays including *E. coli*, while 30 µg of vancomycin was assigned as the C^+ for the assays involving *S. aureus*. For the antifungal assay, 30 µg of clotrimazole was used as the C^+ for both *C. albicans* and *A. niger*. The plates were incubated at 37 °C for 24 h. At the end, the diameter of the inhibition zone appearing around each well was measured as a suitable parameter for evaluating the antibacterial and antifungal activity of the samples. The assays were performed using two independent replicates (two separate disks), and the diameter of inhibition zone was measured twice for the sample in each replicate, resulting in four measurements (n=4). Besides, two measurements were done for C^- and C^+ samples (n=2).

2.6. Minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) assays

The MIC experiments were done on S. aureus bacteria (ATCC 29213) in accordance with broth macrodilution technique. In this regard, fresh cultures of *S. aureus* bacteria were used in order to prepare bacterial suspensions equivalent to 0.5 McFarland. Then, the resulting suspension was diluted at a ratio of 1:100 on Mueller-Hinton broth in order to obtain an inoculum of 5×10^5 CFU mL^{-1} (CFU is the abbreviation for colony forming unit). In the next step, serial dilutions of the green-synthesized Ag were prepared using sterile distilled water to obtain concentrations ranging from 0.125 to 1024 ppm, transferring subsequently 1 mL of which into separate sterile test tubes.

Afterward, 1 mL of the bacterial inoculum was added to each tube, resulting in a twofold dilution of the initially prepared concentrations, 0.125 to 1024 ppm, and yielding final concentrations of 0.0625 to 512 ppm (Figure 1). Tube containing both 1 mL growth



Figure 1. Schematic illustration of the serial dilution of green-synthesized Ag and preparation of the final concentrations of 0.0625 to 512 ppm following the addition of bacterial inoculum.

medium and 1 mL bacterial suspension was assigned as positive control. On the other hand, tube with 2 mL Mueller-Hinton broth medium was designated as negative control. Ultimately, all the tubes were incubated at 37 °C for 24 h. The MIC factor was determined as the lowest concentration of the sample at which the bacterial growth was completely inhibited.

For MBC determination, aliquots from the tubes showing no turbidity or in other words, no visible bacterial growth were cultured on Mueller-Hinton agar plates. The plates were then incubated for 24 h using temperature of 37 °C. The lowest concentration at which no visible colony growth appeared was considered as MBC.

3. Results and Discussion

3.1. Characterization analyses

Figure 2 represents the X-ray diffractogram of the synthesized silver, which is portrayed from 20 to 80 °C. Accordingly, the peaks centered at 38.14, 44.34, 64.38, and 77.38° respectively correspond to the Miller indices of (111), (200), (220), and (311), indicating the face-centered cubic (fcc) structure of silver (17,18).

Besides these peaks, other diffraction peaks are detectable at 27.99, 32.38, and 46.26°, which are marked with asterisk (*). Some literature stated that those peaks are respectively associated with (210), (122), and

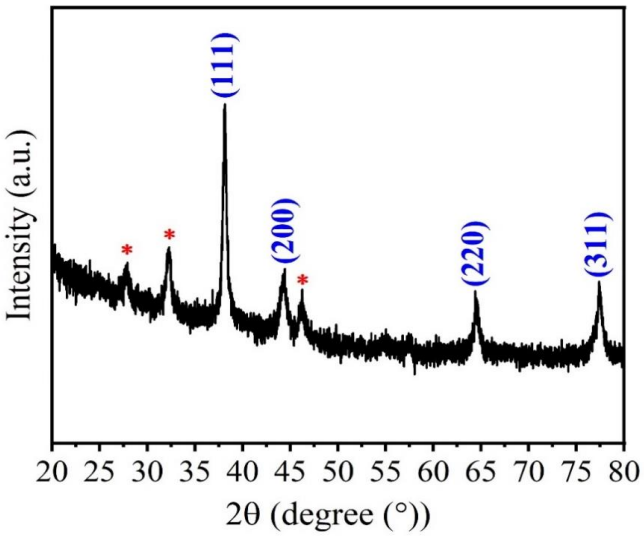


Figure 2. X-ray diffractogram showing crystal structure of synthesized silver powder illustrated in the 2θ range of 20 to 80°.

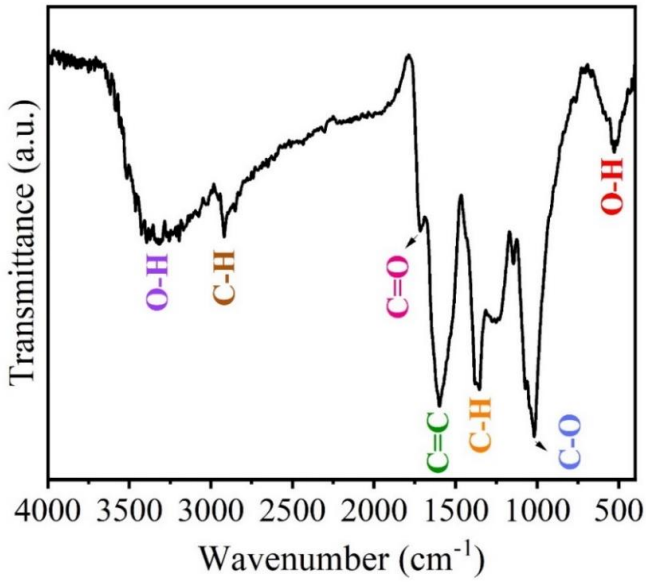


Figure 3. FTIR spectrum of green-synthesized silver powder in the wavenumber range of ~400 to 4000 cm^{-1}, highlighting the major functional groups present in the sample.

(231) crystal planes of silver (19). However, in other references, the peaks at 27.99, 32.38, and 46.26° are ascribed to reducing agents of phytochemical compounds present in the plant extract (20,21). Nevertheless, the peaks exhibiting silver are predominant, implying that silver constitutes the major part of the powder.

The FTIR spectrum of the synthesized silver is depicted in Figure 3. In this regard, the broad peak observable at the wavenumber of 3300 cm^{-1} is associated with stretching vibration of hydroxyl (O–H) groups (22). Furthermore, the peak at 2917 cm^{-1} represents the stretching vibration of C–H (22). The peak centered at 1720 cm^{-1} pertains to the stretching vibration of carbonyl (C=O) (23). The peak found at 1600 cm^{-1} is relevant to the stretching vibration of the C=C double bond (23). The peak at the wavenumber of 1355 cm-1 corresponds to the bending vibration of C–H (22). The peak detectable at 1018 cm^{-1} is imputed to the stretching vibration of the ether group

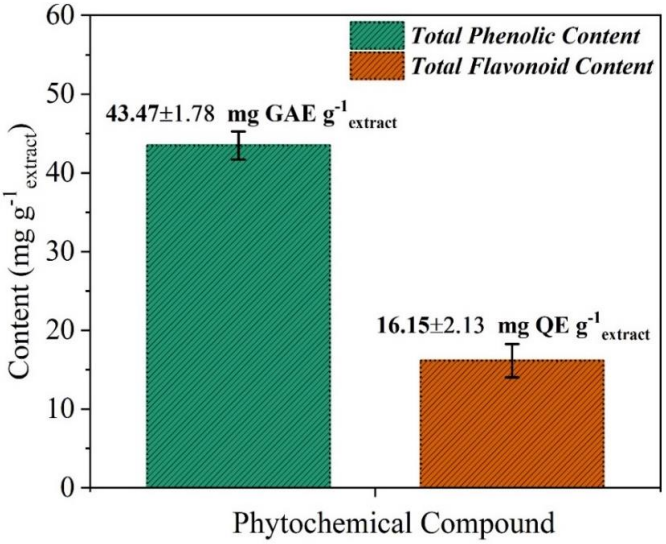


Figure 4. Total phenolic content and total flavonoid content of *E. camaldulensis* leaves extract, expressed per gram of the extract. Values are presented as the mean ± standard deviation (SD) of three independent replicates (n=3). Error bars denote SD.

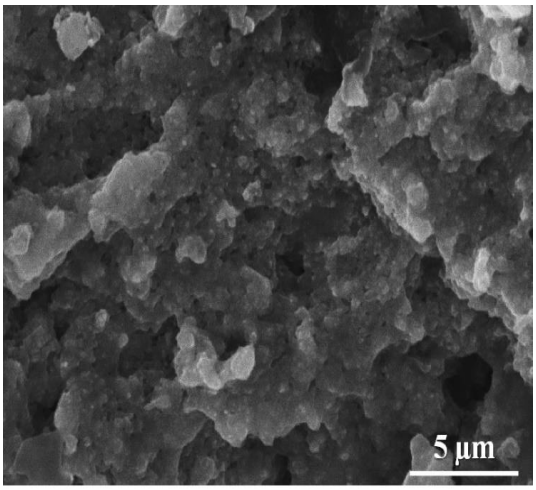


Figure 5. SEM image illustrating the surface morphology of green-synthesized silver powder recorded in the scale bar of 5 µm.

(C–O) (22). The peak seen at 526 cm-1 is pertinent to bonds appearing between the oxygen atoms present in hydroxyl groups with other groups (22).

The observed functional groups are associated with different phytochemical compounds present in the extract of *E. camaldulensis* leaves, in particular phenolic compounds and flavonoids. As evidenced from Figure 4, the TPC of the *E. camaldulensis* leaves extract was determined to be 43.47±1.78 mg GAE g-1extract, while its TFC was found to be 16.15±2.13 mg QE g-1extract, showing the presence of phenolic compounds and flavonoids, which can contribute to the reduction of Ag+ ions to metallic Ag^0. In accordance with literature (24), other functional groups detected in FTIR analysis such as, hydroxyl, carbonyl, and C-O-containing groups may interact with the surface of Ag particles during formation and generate phytochemical-rich capping layers. Terpenoid and other oxygen-containing constituents may also be responsible for surface stabilization (24).

3.2. Antibacterial and antifungal assay

Figure 6 represents the inhibition zones produced by the synthesized Ag against *E. coli*, *S. aureus*, *C. albicans*, and *A. niger* microorganisms. The corresponding antimi-

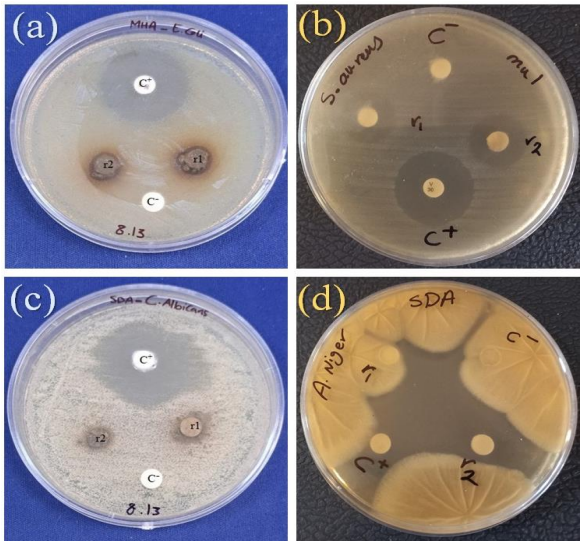


Figure 6. Disk diffusion assay illustrating the inhibition zones produced by green-synthesized silver against (a) *E. coli*, (b) *S. aureus*, (c) *C. albicans*, and (d) *A. niger* and their comparison with the negative (C^-) and positive (C^+) controls.

Table 1. Inhibition zone of green-synthesized Ag against different bacteria and fungi and its comparison with positive (C^+) and negative (C^-) control samples. The results were reported as mean ± SD, where the number of measurements for the sample (Ag) and C^+ samples respectively were n=4 and n=2.

Microorganism	Inhibition Zone (mm)				
	Ag	Chloramphenicol (C^+)	Vancomycin (C^+)	Clotrimazole (C^+)	Distilled water (C^-)
E. coli	12.38±0.48	28.20±0.20	-	-	Not detected
S. aureus	17.13±0.25	-	26.05±0.05	-	Not detected
C. albicans	10.88±0.63	-	-	34.25±0.25	Not detected
A. niger	Not detected	-	-	Not detected	Not detected

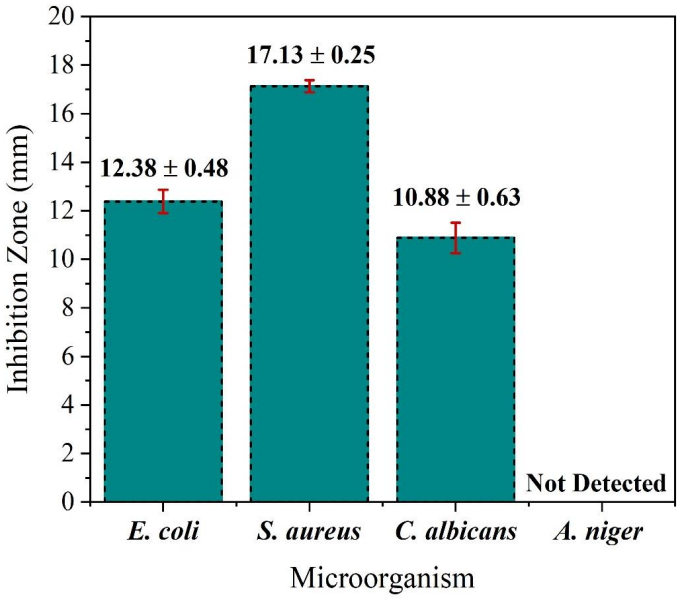


Figure 7. Comparison of antimicrobial activity of green-synthesized Ag against different microorganisms based on the diameter of the inhibition zones. The SD values are shown by error bars.

crobial activity results are tabulated in Table 1 and compared in Figure 7. Accordingly, no inhibition zone was detected for the distilled water (C^-) against any of the microorganisms, demonstrating that the solvent itself had no inhibitory effect.

Hence, MIC and minimum fungicidal concentration (MFC) assays were subsequently carried out to further study the antifungal activity of synthesized Ag against A. niger and to provide more comprehensive assessment of its inhibitory effects. The MIC and MFC assays were done based on the procedure previously delineated for *S. aureus* (Section 2.6) and their corresponding results are summarized in Table 2. As evidenced from Figure 8, no visible fungal growth at the top of broth is detectable at the concentration of 64 mg L^{-1} and beyond; consequently, the MIC and MFC were determined to be 64 mg L^{-1}. These results show antifungal activity of synthesized Ag against *A. niger.*

3.3. MIC and MBC analyses

The MIC and MBC of green-synthesized Ag were assessed against *S. aureus* bacteria, which exhibited the highest antimicrobial activity among the tested microorganisms

Table 2. MIC and MFC values obtained for green-synthesized Ag against *A. niger* fungus.

Fungus	MIC (mg L^{-1})	MFC (mg L^{-1})
A. niger	64	64

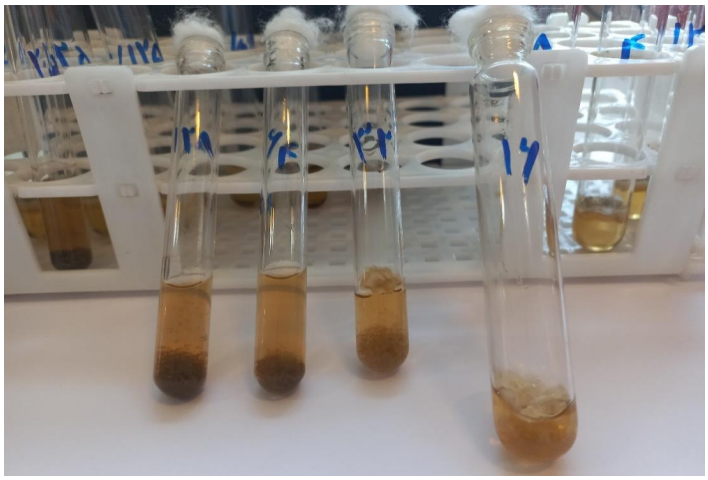


Figure 8. MIC and MFC assays conducted for synthesized Ag against *A. niger* fungus strain. No evident fungal growth (on the top of broth) is detectable at the concentration of 64 mg L^{-1}, disclosing complete inhibition of fungal growth at this concentration.

in the disk diffusion assay. In this regard, MIC value of 128 mg L^{-1} and MBC value of 512 mg L^{-1} were obtained for the sample (Table 3), indicating that it was capable of inhibiting the visible growth of S. aureus at a concentration of 128 mg L^{-1}, while higher concentration of 512 mg L^{-1} was required to achieve a bactericidal effect (Figure 9).

4. Conclusion

In the current work, silver was prepared using a green route where *E. camaldulensis* leaves extract was employed as the reducing agent. Various characterization analyses were hired in order to structurally examine the green-synthesized silver. Moreover, the antibacterial and antifungal properties of the case-study sample was characterized by

Table 3. Evaluation of MIC and MBC of green-synthesized Ag against S. aureus bacterium.

Bacterium	MIC (mg L^{-1})	MBC (mg L^{-1})
S. aureus	128	512

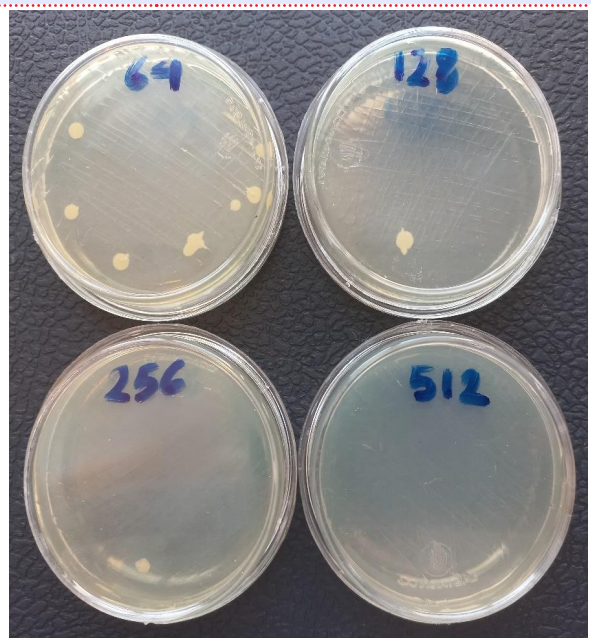


Figure 9. Determination of MIC and MBC values of green-synthesized Ag against *S. aureus* based on colony growth.

means of disk diffusion test along with MIC, MBC, and MFC assays.

In accordance with XRD results, the green-synthesized powder predominantly contained silver. FTIR analysis along with TPC and TFC measurements revealed the existence of phenolic and flavonoid compounds in the *E. camaldulensis* leaves extract, which could act as reducing agents and contribute to the conversion of Ag^{+} ions into metallic Ag^{0} during the green synthesis of silver.

According to assays, green-synthesized silver manifested antimicrobial activity against *E. coli, S. aureus*, *C. albicans*, and *A. niger* microorganisms. Based on the obtained results, our study could pave the way for the preparation of silver in a facile and affordable manner without using toxic chemicals. Our research is at an early stages; but and with further investigation, green-synthesized silver could show potential as an antimicrobial agent for applications where antibacterial and antifungal activity is required.

Acknowledgements

This study has been supported by Quality Control Laboratory in the Department of Food and Drug at Jahrom University of Medical Sciences.

Funding

This research received no external funding.

Authors Contributions

Behrooz Mosallanejad: Conceptualization, Methodology, Data collection, Visualization, Formal analysis, Data curation, and Writing-review & editing.

Raziey Parastan: Supervision, Project Administration, Conceptualization, Methodology, Investigation, Resources, Data collection, Validation, and Writing-review & editing.

Masumeh Ranjbar: Conceptualization, Methodology, Data collection, Investigation, Writing-review & editing.

Saeede Safajoo: Methodology, and Writing-review & editing.

Fateme Darooghe: Methodology, and Writing-review & editing.

Abolfazl Rahmaneian: Methodology, Writing-review & editing.

Ahmad Ahmadi Daryakenari: Resources, Investigation, Methodology, and Writing-review & editing.

Conflict of Interest

The authors declare that they have no conflict of interest.

References

1. Paosen S, Jindapol S, Soontarach R, Voravuthikunchai SP. Eucalyptus citriodora leaf extract-mediated biosynthesis of silver nanoparticles: broad antimicrobial spectrum and mechanisms of action against hospital-acquired pathogens. *APMIS.* 2019;127(12):764-78. doi: 10.1111/apm.12993. Epub 2019 Oct 22. PMID: 31512767.
2. Tripathi A, Sirohi R. Antimicrobial activities of silver nanoparticles synthesized from peel of fruits and vegetables. *Biol Insights.* 2016;1:29-34.
3. Belay WY, Getachew M, Tegegne BA, Teffera ZH, Dagne A, Zeleke TK, *et al*. Mechanism of antibacterial resistance, strategies and next-generation antimicrobials to contain antimicrobial resistance: a review. *Front Pharmacol.* 2024;15:1444781. doi: 10.3389/fphar.2024.1444781. PMID: 39221153; PMCID: PMC11362070.
4. Wang C, Wei X, Zhong L, Chan CL, Li H, Sun H. Metal-Based Approaches for the Fight against Antimicrobial Resistance: Mechanisms, Opportunities, and Challenges. *J Am Chem Soc.* 2025;147(15):12361-80. doi: 10.1021/jacs.4c16035. Epub 2025 Mar 10. PMID: 40063057; PMCID: PMC12007004.
5. Alfuraydi AA, Devanesan S, Al-Ansari M, AlSalhi MS, Ranjitsingh AJ. Eco-friendly green synthesis of silver nanoparticles from the sesame oil cake and its potential anticancer and antimicrobial activities. *J Photochem Photobiol B.* 2019;192:83-9. doi: 10.1016/j.jphotobiol.2019.01.011. Epub 2019 Jan 26. PMID: 30710829.
6. Allahverdy J, Jafari SM. Silver nanoparticles for inactivation and destruction of foodborne pathogens and

spoilage microorganisms; mechanisms, efficiency and recent advances. *Future Foods.* 2025;13:100889. https://doi.org/10.1016/j.fufo.2025.100889.
7. Rodrigues AS, Batista JGS, Rodrigues MÁV, Thipe VC, Minarini LAR, Lopes PS, *et al*. Advances in silver nanoparticles: a comprehensive review on their potential as antimicrobial agents and their mechanisms of action elucidated by proteomics. *Front Microbiol.* 2024;15:1440065. doi: 10.3389/fmicb.2024.1440065. PMID: 39149204; PMCID: PMC11325591.
8. González-Fernández S, Blanco-Agudín N, Rodríguez D, Fernández-Vega I, Merayo-Lloves J, Quirós LM. Silver Nanoparticles: A Versatile Tool Against Infectious and Non-Infectious Diseases. *Antibiotics (Basel).* 2025;14(3):289. doi: 10.3390/antibiotics14030289. PMID: 40149100; PMCID: PMC11939477.
9. Pereira J, Proaño O, Albán A, Zambonino M, Mouheb L, Desmau M, *et al*. Paradoxical Features Empower Biogenic Silver Nanoparticles. *Molecules*. 2025;30(21):4152. doi: 10.3390/molecules30214152. PMID: 41226116; PMCID: PMC12608024.
10. Ren YY, Yang H, Wang T, Wang C. Bio-synthesis of silver nanoparticles with antibacterial activity. Mater. *Chem. Phys.* 2019;235:121746. https://doi.org/10.1016/j.matchemphys.2019.121746.
11. Phongtongpasuk S, Poadang S, Yongvanich N. Environmental-friendly method for synthesis of silver nanoparticles from dragon fruit peel extract and their antibacterial activities. *Energy Procedia*. 2016;89:239-47. https://doi.org/10.1016/j.egypro.2016.05.031.
12. Maj W, Pertile G, Różalska S, Skic K, Frąc M. Comprehensive antifungal investigation of natural plant extracts against Neosartorya spp. (Aspergillus spp.) of agriculturally significant microbiological contaminants and shaping their metabolic profile. *Sci Rep*. 2024;14:8399. https://doi.org/10.1038/s41598-024-58791-4.
13. Mohammed AE. Green synthesis, antimicrobial and cytotoxic effects of silver nanoparticles mediated by Eucalyptus camaldulensis leaf extract. *Asian Pac J Trop Biomed.* 2015;5:382-6. https://doi.org/10.1016/S2221-1691(15)30373-7.
14. Rocha V, Ferreira-Santos P, Aguiar C, Neves IC, Tavares T. Valorization of plant by-products in the biosynthesis of silver nanoparticles with antimicrobial and catalytic properties. *Environ Sci Pollut Res.* 2024;31:14191-14207. https://doi.org/10.1007/s11356-024-32180-w.
15. Wojdyło A, Oszmiański J, Czemerys R. Antioxidant activity and phenolic compounds in 32 selected herbs. *Food chem*. 2007;105:940-9. doi:10.1016/j.foodchem.2007.04.038.
16. Palma A, Díaz MJ, Ruiz-Montoya M, Morales E, Giráldez I. Ultrasound extraction optimization for bioactive molecules from Eucalyptus globulus leaves through antioxidant activity. *Ultrason Sonochem.* 2021;76:105654. doi: 10.1016/j.ultsonch.2021.105654. Epub 2021 Jun 25. PMID: 34198128; PMCID: PMC8254034.
17. Garibo D, Borbón-Nuñez HA, de León JND, García Mendoza E, Estrada I, Toledano-Magaña Y, *et al*. Green synthesis of silver nanoparticles using Lysiloma acapulcensis exhibit high-antimicrobial activity. *Sci Rep.* 2020;10(1):12805. doi: 10.1038/s41598-020-69606-7. PMID: 32732959; PMCID: PMC7393152.
18. S S P, Rudayni HA, Bepari A, Niazi SK, Nayaka S. Green synthesis of Silver nanoparticles using Streptomyces hirsutus strain SNPGA-8 and their characterization, antimicrobial activity, and anticancer activity against human lung carcinoma cell line A549. *Saudi J Biol Sci.* 2022;29(1):228-38. doi: 10.1016/j.sjbs.2021.08.084. Epub 2021 Aug 28. PMID: 35002413; PMCID: PMC8716891.
19. Wang L, Wu Y, Xie J, Wu S, Wu Z. Characterization, antioxidant and antimicrobial activities of green synthesized silver nanoparticles from Psidium guajava L. leaf aqueous extracts. *Mater Sci Eng C Mater Biol Appl.* 2018 1;86:1-8. doi: 10.1016/j.msec.2018.01.003. Epub 2018 Feb 16. PMID: 29525084.
20. Ohiduzzaman M, Khan MNI, Khan

KA, Paul B. Biosynthesis of silver nanoparticles by banana pulp extract: Characterizations, antibacterial activity, and bioelectricity generation. *Heliyon.* 2024;10(3):e25520. doi: 10.1016/j.heliyon.2024.e25520. PMID: 38327438; PMCID: PMC10848009.

21. Anandalakshmi K, Venugobal J, Ramasamy VJAN. Characterization of silver nanoparticles by green synthesis method using Pedalium murex leaf extract and their antibacterial activity. *Appl Nanosci.* 2016;6:399-408. https://doi.org/10.1007/s13204-015-0449-z.
22. Wan Mat Khalir WKA, Shameli K, Jazayeri SD, Othman NA, Che Jusoh NW, Hassan NM. Biosynthesized Silver Nanoparticles by Aqueous Stem Extract of Entada spiralis and Screening of Their Biomedical Activity. *Front Chem.* 2020;8:620. doi: 10.3389/fchem.2020.00620. PMID: 32974269; PMCID: PMC7466720.
23. Rygula A, Klisińska-Kopacz A, Krupska P, Kuraś E, del Hoyo-Meléndez JM. The surface degradation of Baltic amber: The depth-profiling analysis and its application to historical object. *J Raman Spectrosc.* 2021;52:123-9. https://doi.org/10.1002/jrs.5942.
24. Alghoraibi I, Soukkarieh C, Zein R, Alahmad A, Walter JG, Daghestani M. Aqueous extract of Eucalyptus camaldulensis leaves as reducing and capping agent in biosynthesis of silver nanoparticles. *Inorg Nano-Met Chem* 2020;50:895-902. https://doi.org/10.1080/24701556.2020.1728315.