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Original Article

Aqueous Extract-Mediated Green Synthesis of Silver Nanoparticles Using Euphorbia resinifera: Effect of Calcination on Crystallinity, Thermal Stability, and Antibacterial Activity

Amal A. Muftah[1] , Abubakar Abutartour[2] , Aisha Suliman Aldroujee1[3] , Sharda Gadale[4] , Khadija Esaga[2] , Heba Miftah[2]

[1]*Faculty of Education, Tripoli University, Libya*

[2]*Libyan Advanced Center for Chemical Analysis – Libyan Authority for Scientific Research*

[3]*Faculty of Sciences, Al-Zintan University, Libya*

[4]*Yashwantrao Mohite College, Bharati Vidyapeeth (Deemed to Be University), Pune, India.*

***Corresponding author**, Amal A. Muftah. Email:* www.amalmoftah@bwu.edu.ly

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Abstract

Background: This study presents the green synthesis of silver nanoparticles (AgNPs) using an aqueous extract of *Euphorbia resinifera*. **Methods:** The synthesis of AgNPs was conducted using *Euphorbia resinifera* extract as a reducing and capping agent. The resulting nanoparticles were characterised using UV-Vis spectroscopy, thermogravimetric analysis (TGA), and X-ray diffraction (XRD). Crystallite sizes were evaluated using the Scherrer equation, and the antibacterial potential of the synthesized AgNPs was assessed against Staphylococcus aureus and Escherichia coli. **Results:** UV–Vis spectroscopy revealed a distinct surface plasmon resonance (SPR) peak at 421 nm with an absorbance of 0.47, confirming AgNP formation. TGA demonstrated that uncalcined AgNPs underwent a 37–38% weight loss up to 600 °C due to organic decomposition, whereas calcined AgNPs retained~91% mass stability at 600 °C. XRD analysis confirmed a face-centred cubic (FCC) structure with reflections at (111), (200), (220), and (311) planes. Following calculation, the apparent crystallite-domain size increased from 32.9 to 54.8 nm, accompanied by a decrease in FWHM from 0.2558° to 0.1535°. Additionally, the synthesized AgNPs exhibited clear antibacterial activity against both S. aureus and E. coli. **Conclusion:** These findings demonstrated that *Euphorbia resinifera* is a viable source for the green synthesis of crystalline, biologically active silver-containing nanomaterials.

Keywords: Silver nanoparticles, *Euphorbia resinifera*, green synthesis, calcination, crystallinity, antibacterial activity.

Introduction

In modern materials science, nanotechnology is a highly innovative research field, making significant contributions to life sciences, particularly biotechnology and biomedical fields. [1] Specifically, nanotechnology has transformed drug delivery systems due to the nanometer particle size, high surface area, enhanced physicochemical stability, and biocompatibility of nanomaterials. In addition, it improves drug solubility, permeability, and bioavailability regardless of the drug's physical properties [2].

Nanomedicine is one of the recently emerging fields, which involves the use of nanoparticles as drug delivery systems to potentiate the therapeutic action of a phytochemical agent. Among all used nanoparticles, the noble silver nanoparticles (AgNPs) gain great interest due to their wide applications in the medical field[3].

Natural products used in traditional medicine have long served as the foundation for modern drug discovery [4]. The secondary metabolites from plants, particularly phenolics and flavonoids, are well documented as potent free radical scavengers. [5], and effective antimicrobial agents [6]. Biological matrices, most notably plant extracts, serve as highly efficient green red ucing and stabilizing agents, leveraging their constituent phytochemicals to convert precursor metal salts into functional metallic nanoparticles. [7]

Extracts derived from various plant parts such as leaves, roots, stems, seeds, flowers, and fruit peels contain rich bioactive compounds that serve as effective reducing agents for synthesizing diverse inorganic nanoparticles [8], [9]. Among these, a wide spectrum of noble metals such as silver, gold, palladium, and platinum serves as key starting materials in green nanomaterial synthesizes [10], [11].

Plant-mediated synthesis of silver nanoparticles (AgNPs) has attracted significant research interest as an eco-friendly, cost-effective, and straightforward approach, where plant biomolecules act as effective stabilizing and reducing agents [12], [13].

Synthesis parameters significantly influence the physicochemical properties of AgNPs, including size, morphology, and surface characteristics, as governed by the employed plant species and reaction conditions [14]. Thus, among the metal nanoparticles, silver nanoparticles (AgNPs) stand out due to these tailored features, which confer distinguished antibacterial, antiviral, and anticancer activities [15].

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Deriven by the rapid expansion of nanotechnology across biomedical, pharmaceutical, and environmental disciplines [16], silver nanoparticles (AgNPs) have gained significant research attention due to their versatile functional applications, including antibacterial, antifungal, antioxidant, and antitumor activities, as well as catalytic dye degradation. [17]

Noble metal nanoparticles exhibit size-dependent physicochemical properties, including mechanical and biological characteristics, catalytic activity, thermal and electrical conductivity and distinct optical properties. These valuable properties are utilized for widespread applications in catalysis, electronics, optics, environment and biomedicine [18], [19].

Compared to bulk materials, nanoparticles exhibit distinct physical characteristics that are governed by their size, shape, morphology, and distribution [20], [21].

Libya hosts a wide variety of ecosystems extending from Mediterranean coastal regions to arid desert landscapes, providing diverse habitats that support a rich flora [22]. Among these, medicinal and aromatic plants growing in Libya were first briefly documented in a report by the United Nations Educational, Scientific and Cultural Organisation [23].

Euphorbia is the most prominent genus in the Euphorbiaceae family, with over 2000 accepted species [24], [25]. Phytogeographically, the genus *Euphorbia* is predominantly native to Africa, having subsequently diversified across disparate global ecosystems including the Americas, Western Asia, and Central Mexico, while serving as a prime botanical source of structurally diverse polycyclic diterpenes [26], [15].

Due to these characteristics, *Euphorbia* genus species are frequently utilized in traditional medicine, including traditional Chinese medicine, due to their rich bioactive and pharmacological relevance [27], [28]. Indeed, the genus Euphorbia is being intensely investigated, especially due to the possibilities offered by technology with the association of stabilizing nanomolecules by pharmaceutical chemists [29].

Among these species, Euphorbia resiniferousO. Berg, exemplifies the intersection of ecological importance, traditional knowledge, and modern scientific interest [30]. Specifically, the traditional medicinal applications and therapeutic potential of *Euphorbia resinifera* are closely linked to its rich chemical constituents and underlying biological mechanisms [31], [32].

Euphorbia resiniferaL. possesses a rich phytochemical matrix; Benmehdi et al. [33] demonstrated that its phenolic-, flavonoid-, and tannin-rich extracts, along with its honey and propolis, exhibit strong antioxidant capacity, broad antifungal potential, and selective antibacterial efficacy against Escherichia coli. Building on these intrinsic properties, Euphorbia species have been widely applied as bio-reducers in green nanotechnology. Specifically, research by Nasr and Abdullah [28] and Arif et al. [34] demonstrated that root extracts of Euphorbia spp. And Euphorbia wallichii (20-60 nm) mediated the biosynthesis of Silver nanoparticles (AgNPs) with robust radical scavenging and antibacterial properties. In alignment with these finding, Devi et al. [35] synthesized spherical AgNPs (20-90nm) using Euphorbia nivulia stem extract, showing broad spectrum activity against pathogens like E. coli and Pseudomonas aeruginosa. Furthermore, Thomas et al. [36] developed a facile protocol using Euphorbia gramineaextract to yield quasi-spherical AgNPs (6.77 nm) with high catalytic and antimicrobial efficiency. Extending beyond this genus, Sharma et al. [37] utilized polyphenol-rich extracts of *Centella asiatica* for AgNP fabrication, demonstrating marked antibacterial action against both gram-positive (Staphylococcus aureus) and gram-negative bacteria.

To date, reports on the green synthesis of silver nanoparticles using Euphorbia resinifera extracts remain limited. Therefore, this study aimed to establish a plant-mediated method for synthesizing silver nanoparticles using E. resinifera and to evaluate their antibacterial activity against representative bacterial strains.

Materials and Methods

Silver nitrate ($AgNO_3$) was obtained from Merck, Germany. All stock solutions were prepared using double-distilled, deionized water.

The Euphorbia resinifera plant was collected from Msallata, Libya. The apparatus included conical flasks, Petri dishes, a digital balance, a magnetic stirrer, a mortar and pestle, an oven, a hot plate, a centrifuge, glass rods, droppers, graduated cylinders, Erlenmeyer flasks, cuvettes, a refrigerator, a Teflon-lined autoclave, a hot-air dryer, and a furnace.

Plant extracts preparation

The Euphorbia resinifera plant was dried in the shade under normal environmental conditions and homogenized into a fine powder before use.

Synthesis of Ag nanoparticle

Silver nanoparticles were synthesized using a green approach with silver nitrate. A 0.1 M silver nitrate solution was prepared by dissolving 1.7 g of $AgNO_3$ in a final volume of 100 mL of distilled water. Subsequently, 30 mL of Euphorbia resinifera extract was added to 100 mL of the silver nitrate solution and stirred for 5 min. A 2 M NaOH solution was used to adjust the pH to 9. The reaction mixture was then stirred for 1 h at 60 °C until a greenish slurry formed. The precipitate was collected by centrifugation for 30 min, washed with distilled water and ethanol, and dried at 80 °C. Finally, the dried precursor was calcined at 600 °C for 2 h to produce crystalline silver nanoparticles.

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Characterizations

UV-vis spectroscopy.

UV-Vis absorption double-beam spectrophotometer at 200 -900nm in room temperature was used to analyse the optical properties of the synthesised Ag nanoparticles using deuterium and tungsten-halogen lamps.

Thermogravimetric Analysis (TGA)

Thermogravimetric analysis (TGA) was used to evaluate the thermal stability of the nanomaterials and the thermal decomposition behaviour of organic components associated with their surface.

X-ray diffraction (XRD)

A Bruker D8 Advanced diffractometer (Cu Ka, l = 1.5406 Å) was used to determine the crystallinity at 40 kV, 30 mA, in the 2q range of 10–80° with a step size of 0.02°. The powdered samples were similarly packed on a flat holder. The Debye–Scherrer formula is used to compute the crystallite size

Antibacterial activity

Pure and identified bacterial isolates representing the Gram-positive bacterium Staphylococcus aureus and the Gram-negative bacterium Escherichia coli were used. The purity of the bacterial isolates was confirmed by culturing them on nutrient agar and incubating them at 37 °C for 24 h before the antibacterial assay.

To prepare the bacterial culture, bacterial colonies were transferred to a tube containing 5 mL of physiological saline (0.85% sodium chloride) and thoroughly mixed to obtain the culture. The suspension was adjusted to approximately 0.5 McFarland, corresponding to approximately 1.5×10^8 bacterial cells/mL.

Evaluation of the Antibacterial Activity of Different Silver Nanoparticles

The antibacterial activity of the silver nanoparticles was evaluated before and after calcination at 600 °C using Mueller–Hinton agar (MHA). The medium was inoculated with the prepared bacterial suspension, and the silver nanoparticles were deposited onto the surface of the medium. The plates were incubated at 37 °C for 24 h. After incubation, antibacterial activity was assessed by measuring the diameter of the zone of inhibition (ZOI) around each sample.

Results

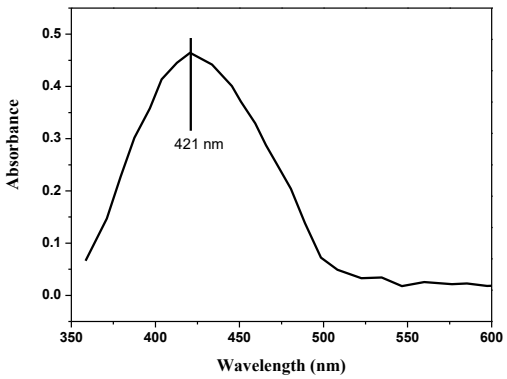


Figure 1: UV–Vis analysis of Ag nanoparticles

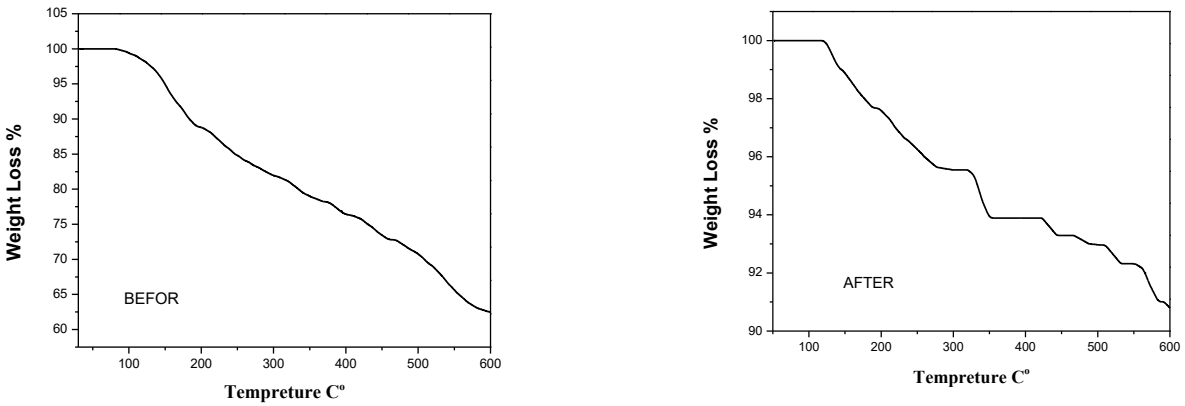


Figure 2:TGA Analysis of Ag nanoparticles

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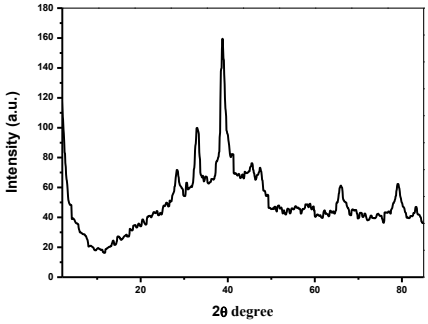


Figure 3: XRD spectrum of AgNPS befor calcination

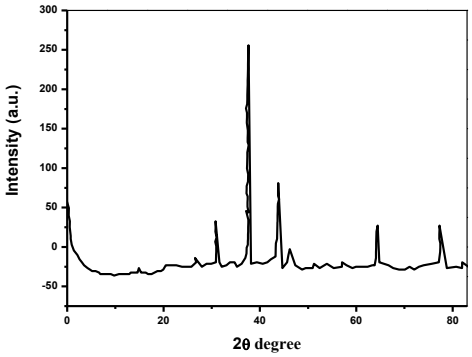


Figure 4: XRD spectrum of AgNPs after calcination

Discussion:

UV-Vis spectroscopy:

UV–Vis spectroscopy was used to assess the synthesis of silver nanoparticles (AgNPs). The UV–Vis spectrum of the biosynthesized AgNPs prepared using the aqueous extract of Euphorbia resinifera exhibited a distinct surface plasmon resonance (SPR) absorption peak at 421 nm, with an absorbance of 0.47. This band is associated with the collective oscillation of conduction-band electrons on the nanoparticle surface and supports the reduction of Ag^{+} to Ag^{0} and the formation of AgNPs.

absorption peak at 421 nm with an absorption value of 0.47. This resonance band arises from the collective oscillation of conduction band electrons on the metallic nanoparticle surface, confirming the successful bio

reduction of Ag+ ions to Ag and the subsequent formation of AgNPs.

Furthermore, the peak's location within the 400-450 nm range is consistent with numerous studies indicating that spherical or semi-spherical silver nanoparticles exhibit absorption peaks within this range. The amplitude of the peak suggests a distribution in the size of the resulting particles, which is expected in green synthesis methods using plant extracts.

Thermogravimetric Analysis (TGA)

In environmentally friendly manufactured silver nanoparticles (AgNPs), TGA provides essential information about the presence of plant-derived phytochemicals adsorbed onto the nanoparticle surface, their role as reducing and coating agents, the amount of organic matter bound to the nanoparticles, and the optimal calcination temperature for obtaining high-purity nanoparticles. Therefore, TGA plays a crucial role in validating the effectiveness of environmentally friendly manufacturing processes and optimizing post-process heat treatment.

The thermogravimetric analysis (TGA) curves of silver nanoparticles before and after calcination are shown in Figure 2. The uncalcined sample exhibited a continuous weight loss of approximately 37–38% up to 600 °C, confirming the presence of a significant amount of volatile substances and plant-derived organic compounds adsorbed onto the nanoparticle surface. The initial weight loss below 150 °C is attributed to the evaporation of physically adsorbed moisture and residual solvents. The second weight loss region (150–350 °C) is attributed to the thermal decomposition of plant-derived phytochemicals, including polyphenols, flavonoids, proteins, carbohydrates, and other biomolecules that acted as reducing and stabilizing (coating) agents during the biosynthesis of silver nanoparticles. The gradual mass loss observed between 350 and 500 °C is attributed to the decomposition of organic residues and more closely bound carbonaceous materials on the nanoparticle surface.

The total weight loss before calcination indicates that approximately 38% of the sample mass consisted of volatile and plant-derived components. The TGA curve showed that most of these components decomposed below 500 °C. Accordingly, calcination at 600 °C was selected as the heat-treatment condition used in this study. Following calcination, the TGA curve shown in Figure 3, the weight reduction of approximately 9% over the studied temperature range, with nearly 91% of the sample mass remaining at 600 °C. This result indicates increased thermal stability after calcination and is consistent with the removal of a substantial proportion of plant-derived organic components.

Overall, the TGA results are consistent with the participation of phytochemicals from the plant extract as reducing and stabilizing agents during synthesis. Calcination at 600 °C removed a substantial proportion of these organic components and produced a more thermally stable material.

X-ray diffraction

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X-ray diffraction (XRD) analysis was performed to confirm the crystalline nature of the synthesized silver nanoparticles. The diffraction pattern showed peaks at approximately 2θ = 38.6°, 44.9°, 65.1°, and 77.8°, corresponding to the (111), (200), (220), and (311) planes, respectively. These peaks are characteristic of the face-centred cubic (FCC) structure of metallic silver and are consistent with the JCPDS standard for silver (No. 04-0783). Weak additional peaks around 28.5°, 33.0°, 46.9°, and 51.0° may be associated with residual compounds or minor impurities.

To assess the effect of calcination on the structural properties of the synthesized nanoparticles, XRD patterns recorded before and after calcination were compared. Both samples exhibited the FCC crystalline phase of metallic silver. After calcination, the intensity of the dominant (111) reflection increased, while its FWHM decreased from 0.2558° to 0.1535°. The apparent crystallite size estimated using the Scherrer equation increased from approximately 32.9 nm to 54.8 nm. The decrease in the broad amorphous background is consistent with the removal of residual organic compounds. These results indicate that heat treatment increased crystallinity and apparent crystallite-domain size without changing the identified FCC phase.

Overall, the XRD results support the formation of crystalline silver nanoparticles and indicate that calcination increased the apparent crystallinity and crystallite-domain size while retaining the FCC crystal structure.

Antibacterial activity of silver nanoparticles

The antibacterial activity tests showed inhibition zones around the prepared silver nanoparticles against both Gram-positive Staphylococcus aureus and Gram-negative Escherichia coli. These observations indicate that the prepared material inhibited the growth of the tested bacteria.

Furthermore, a comparison between the silver nanoparticles before calcination and those that underwent calcination at 600°C revealed a difference in inhibitory activity against the tested bacteria. This difference is attributed to changes in the physical and crystalline properties of the nanoparticles resulting from the heat treatment. X-ray diffraction (XRD) results showed that calcination improved crystallinity and increased crystal size. These changes may be reflected in the interaction between the nanoparticle surface and bacterial cells, and consequently in their inhibitory capacity.

The antibacterial activity of silver nanoparticles may involve interaction with the bacterial cell surface, release of Ag^+ ions, disruption of membrane permeability, interference with cellular components, and oxidative stress. These mechanisms are possible explanations for the observed inhibition.

Conclusion

In conclusion, silver nanoparticles were synthesized through an eco-friendly green route using Euphorbia resinifera extract. UV–Vis spectroscopy showed an SPR band at 421 nm, while TGA indicated the removal of a substantial proportion of plant-derived organic components after calcination. XRD confirmed the FCC crystalline phase of silver and showed an increase in apparent crystallite-domain size after heat treatment. The prepared nanoparticles showed antibacterial activity against Staphylococcus aureus and Escherichia coli. These results support the potential of Euphorbia resinifera extract as a reducing and stabilizing medium for the green synthesis of silver-containing nanomaterials.

Conflict of Interest

There is no financial, personal, or professional conflict of interest regarding the publication of this study.

References

1. Khandel, P., Yadaw, R. K., Soni, D. K., Kanwar, L., & Shahi, S. K.
(2018). Biogenesis of metal nanoparticles and their pharmacological applications: Present status and application. *Journal of Nanostructure in Chemistry*, 8(3), 217–254.
https://doi.org/10.1007/s40097-018-0267-4

2- El-Attar, N. A., El-Sawi, M. R., & El-Shabasy, E. A. (2025). The prophylactic effect of Ficus carica nanoparticles on C57BL/6 female mice infected with Schistosoma mansoni. Research Square. https://doi.org/10.21203/rs.3.rs-5735794/v1

3- Al Mutairi, J. F., Al-Otibi, F., Alhajri, H. M., Alharbi, R. I., Alarifi, S., & Alterary, S. S. (2022). Antimicrobial activity of green silver nanoparticles synthesized by different extracts from the leaves of Saudi palm tree (Phoenix dactylifera L.). Molecules, 27(10), Article 3113. https://doi.org/10.3390/molecules27103113

4- Aldroujee, A. S., Hebail, F. O., Muftah, A. A., & Kumar, S. (2023). Estimation of total phenolics and flavonoids content of banana pulp and peel. Al-Riyadah Journal for Researches and Scientific Activities, (8).

5- Aldroujee, A. S., Muftah, A. A., & Kumar, S. (2022, September 4). Antioxidant potential of different extracts of banana (pulp and peel) [Paper presentation]. The 6th Annual Conference on Theories and Applications of Basic and Biosciences, Misurata University, Libya.

6- Buzgaia, N., Awin, T., Elabbar, F., Abdusalam, K., Lee, S. Y., Rukayadi, Y., Abas, F., & Shaari, K. (2020). Antibacterial activity of Arbutus pavarii Pamp against methicillin-resistant Staphylococcus aureus (MRSA) and UHPLC-MS/MS profile of the bioactive fraction.

DOI: https://doi.org/10.54361/LJMR.20.3.103

Libyan Journal of Medical Research

www.lmjr.ly/ E.ISSN: 2413-6096

Plants, 9(11), Article 1539. https://doi.org/10.3390/plants9111539

7- Akhtar, U., Tallal, M., Sattar, R., & Ishaq, T. (2025). Green synthesis of tin oxide nanoparticles from plant extracts: Characterization and assessment of photocatalytic, antibacterial, and antimicrobial activities. Conclusions in Engineering. https://doi.org/10.71107/t52gt907

8- Darakli, M. A. R., & Abou Hassan, M. A. (2024). Green synthesis of silver nanoparticles using figs (Ficus carica L.) leaves extract Syrian. Nanosistemi, Nanomateriali, Nanotehnologii, 22(2), 469–479. https://doi.org/10.15407/nnn.22.02.469

9- Villagrán, Z., Anaya-Esparza, L. M., Velázquez-Carriles, C. A., Silva-Jara, J. M., Ruvalcaba-Gómez, J. M., Aurora-Vigo, E. F., Rodríguez-Lafitte, E., Rodríguez-Barajas, N., Balderas-León, I., & Martínez-Esquivias, F. (2024). Plant-based extracts as reducing, capping, and stabilizing agents for the green synthesis of inorganic nanoparticles. Resources, 13(6), Article 70. https://doi.org/10.3390/resources13060070

10- Devi, N. S., Padma, Y., & Venkata Raju, R. R. (2021). Green synthesis of silver nanoparticles through reduction with Euphorbia nivulia Buch.-Ham., stem bark extract: Characterization and antimicrobial activity. Journal of Pharmacognosy and Phytotherapy, 13(2), 60-67. https://doi.org/10.5897/JPP2020.05

11- Banakari, M., Shahbazi, Z., Mousavi, S. M., Hashemi, S. A., & Lai, C. W. (2022). Herbal green nanomaterials and their applications. In C. Baskar et al. (Eds.), Encyclopedia of Green Materials. Springer Nature Singapore. https://doi.org/10.1007/978-981-16-4921-9_57-1

12- Muftah, A. A., Waghmode, S., & Gadale, S. (2019). Green synthesis and antimicrobial activity of silver nanoparticles using Rosmarinus officinalis leaves extract. Bio-Materials and Technology, 1(1), 48–54.

13- Bawazeer, S. (2025). Green synthesis: An eco-friendly approach for the synthesis of silver nanoparticles functionalized with Operculina turpethum and it's in vitro and in vivo biological activities. International Journal of Nanomedicine, 20, 2991–3005. https://doi.org/10.2147/IJN.S

14- Eker, F., Akdaşçi, E., Duman, H., Bechelany, M., & Karav, S. (2025). Green synthesis of silver nanoparticles using plant extracts: A comprehensive review of physicochemical properties and multifunctional applications. International Journal of Molecular Sciences, 26(13), Article 6222. https://doi.org/10.3390/ijms26136222

15- da Rosa, R. L., Campos, P. M., Cruz, L. S., Novak, R. S., Kanunfre, C. C., Esmerino, L. A., Schebelski, D. J., de Paula, J. F. P., & Beltrame, F. L. (2022). Biomonitorated study of Euphorbia umbellata (Pax) Bruyns extracts to be used to prepare silver nanoparticles with antimicrobial and cytotoxic potential. Research, Society and Development, 11(12), Article e367111234804. https://doi.org/10.33448/rsd-v11i12.34804

16- Kocadağ Kocazorbaz, E. (2021). Green synthesis, optimization, and characterization of silver nanoparticles from Euphorbia rigida leaf extract and investigation of their antimicrobial activities. BŞEÜ Fen Bilimleri Dergisi, 8(2), 512–522. https://doi.org/10.35193/bseufbd.843005

17- Adaila, K. E., Elraies, S. S. E., Omar, A. A., Ben Younis, E. J., Alhaj, H. A., Shlebek, S. A., & Ali, S. N. (2023). Aqueous extract of Winter Jasmine leaves mediated biosynthesis of silver nanoparticles. Scientific Journal for the Faculty of Science-Sirte University, 3(1), 1139. https://doi.org/10.37375/sjfssu.v3i1.1139

18- Kelkawi, A. H. A., Kajani, A. A., & Bordbar, A. K. (2017). Green synthesis of silver nanoparticles using Mentha pulegium and investigation of their antibacterial, antifungal and anticancer activity. IET Nanobiotechnology, 11(4), 370–376. https://doi.org/10.1049/iet-nbt.2016.0103

19- Eker, F., Akdaşçi, E., Duman, H., Bechelany, M., & Karav, S. (2025). Green synthesis of silver nanoparticles using plant extracts: A comprehensive review of physicochemical properties and multifunctional applications. International Journal of Molecular Sciences, 26(13), 6222. https://doi.org/10.3390/ijms26136222

20- Roy, A. (2017). Synthesis of silver nanoparticles from medicinal plants and its biological application: A review. Research & Reviews in Biosciences, 12(4), Article 138.

21- Salunkhe, B., Muftah, A., Waghmode, S., Mandake, A., Patil, D., Shaikh, A. L., & Gadale, S. (2026). Synthesis of Ag–Fe bimetallic nanoparticles using Rosmarinus officinalis leaf extract. Heterocyclic Letters, 16(1), 49–57.

22- El-Mokasabi, F., Omar, N., & El-Garary, E. (2025). Libyan collections in foreign herbaria. Alqalam Journal of Medical and Applied Sciences, 8(1), 221–229. https://doi.org/10.54361/ajmas.258134

23- Abogmaza, A. F., Keer, K. F., Takrizzah, A. A., & Yahya, E. B. (2020). A review on the medicinal and aromatic plants growing in Libya and their therapeutic properties. International Research Journal of Science and Technology, 2(1), 327–334. https://doi.org/10.46378/irjst.2020.020105

24- Elagdi, C., Bouaouda, K., Rahhal, R., Hsaine, M., Badri, W., Fougrach, H., & EL Hajjouji, H. (2023). Phenolic compounds, antioxidant and antibacterial activities of the methanolic extracts of Euphorbia resinifera and Euphorbia echinus. Scientific African, 21, e01779. https://doi.org/10.1016/j.sciaf.2023.e01779

25- Benrahou, K., El Guourrami, O., Naceiri Mrabti, H., Cherrah, Y., & Faouzi, M. E. A. (2022). Investigation of antioxidant, hypoglycemic and anti-obesity effects of

Euphorbia resinifera L. Journal of Pharmacopuncture, 25(3), 242–249. https://doi.org/10.3831/KPI.2022.25.3.242

26- Benjamaa, R., Elbouny, H., Errati, H., Moujanni, A., Kaushik, N., Gupta, R., Ennibi, O., Nasser, B., Choi, E. H., Kaushik, N. K., & Essamadi, A. (2024). Comparative evaluation of antioxidant activity, total phenolic content, anti-inflammatory, and antibacterial potential of Euphorbia-derived functional products. Frontiers in Pharmacology, 15, Article 1345340. https://doi.org/10.3389/fphar.2024.1345340

27-Varricchio, M. C. B. N., Gaspar, S. Á., da Silva, J., Dinóla, I. C. S., da Silva, E. P., da Silva, S., Pyrrho, A. dos S., & Kuster, R. M. (2026). Euphorbia resinifera and traditional medicine. REVISTA OWL (OWL Journal), 4(5). https://doi.org/10.5281/zenodo.20371996

28- Nasr, R. A., & Abdullah, S. M. (2026). Antimicrobial and antioxidant properties of nanoparticles synthesized from Euphorbia spp. extract in the Kurdistan region of Iraq. Kirkuk University Journal for Agricultural Sciences, 17(1). https://doi.org/10.58928/ku26.17127

29- Giorgi, J. dos S. J., Coutinho, B., Leira, M. F., Bolognani, F. de A., Giorgi, M. S., Pyrrho, A. dos S., Branco, M. T. L. C., & Varricchio, M. C. B. N. (2026). Euphorbium (Euphorbia resinifera): A revision study. Revista Projeção e Docência, 17(1), Article e2561. https://doi.org/10.54899/rpd.v17n1-2561

30- Abd-Dada, H., Bouda, S., Dani, S., Bouchari, M. E. H., Adiba, A., & Haddioui, A. (2025). An ethnobotanical study on traditional medicinal uses of Euphorbia resinifera by local communities in Beni Mellal-Khenifra, Morocco. Asian Journal of Ethnobiology, 8(2), 230–244. https://doi.org/10.13057/asianjethnobiol/y080209

31-Hammad, D., Ourhzif, E.-M., Hamri, S., Abderrafia, H., Khouili, M., & Pujol, M. D. (2025). Chemical components of the dried latex of Euphorbia resinifera Berg and its medicinal features. Chemistry & Biodiversity, 22(5), Article e202403067. https://doi.org/10.1002/cbdv.202403067

32-Hmidouche, O., Bouftini, K., Chafik, A., Khouri, S., Rchid, H., Rahimi, A., Mimouni, M., Maarouf, E., Zaakour, F., Nmila, R., & Khouchlaa, A. (2023). Ethnomedicinal use, phytochemistry, pharmacology, and toxicology of Euphorbia resinifera O. Berg. (B): A review. Journal of Zoological and Botanical Gardens, 4(2), 364–395. https://doi.org/10.3390/jzbg4020029

33-Benmehdi, H., Bounoua, N., Amrouche, A., Lahcene, D., & Maazouzi, A. (2013). Phytochemical study, antioxidant and antimicrobial activities of Euphorbia resinifera L. International Research Journal of Pharmacy, 4(9), 85–89. https://doi.org/10.7897/2230-8407.04910

34- Arif, M., Ullah, R., Ahmad, M., Ali, A., Ullah, Z., Ali, M., Al-Joufi, F. A., Zahoor, M., & Sher, H. (2022). Green synthesis of silver nanoparticles using Euphorbia wallichii leaf extract: Its antibacterial action against citrus canker causal agent and antioxidant potential. Molecules, 27(11), Article 3525. https://doi.org/10.3390/molecules27113525

35- Devi, N. S., Padma, Y., & Raju, R. R. V. (2021). Green synthesis of silver nanoparticles through reduction with Euphorbia nivulia Buch.-Ham., stem bark extract: Characterization and antimicrobial activity. Journal of Pharmacognosy and Phytotherapy, 13(2), 60–67. https://doi.org/10.5897/JPP2020.0577

36- Thomas, O. E., Alabi, O. S., & Osharode, P. E. (2023). Characterization, antimicrobial and catalytic activities of silver nanoparticles biosynthesized using aqueous extract of Euphorbia graminea. Acta Pharmaceutica Sciencia, 61(2). https://doi.org/10.23893/1307-2080.APS6112

37- Sharma, K., Bhusal, M., Magar, A. B., Pathak, I., Shrestha, L. K., & Sharma, K. R. (2025). Phytochemical analysis and green synthesis of silver nanoparticles using Centella asiatica leaf and stem extracts: An investigation of antibacterial activity. PLoS ONE, 20(9), Article e0321172. https://doi.org/10.1371/journal.pone.0321172