IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Eco-Friendly Synthesis of Silver Nanoparticles from *Spondias pinnata* Bark: UV–Vis, FESEM, EDX and Zeta Potential Analysis

Dr. Aditi Kuswaha

Assistant Professor, K. B. Women's College, Hazaribagh, Jharkhand, India

Abstract

The development of sustainable nanomaterials through green chemistry approaches has gained significant attention in recent years. In the present study, silver nanoparticles (AgNPs) were synthesized using aqueous bark extract of *Spondias pinnata*, a medicinal plant rich in bioactive phytochemicals. The green synthesis approach eliminates the need for toxic chemical reducing agents and provides a simple, cost-effective, and environmentally benign route for nanoparticle production. The formation of AgNPs was initially confirmed by a visible color change from pale yellow to dark brown due to surface plasmon resonance. The synthesized nanoparticles were characterized using UV–Visible spectroscopy, Field Emission Scanning Electron Microscopy (FESEM), Energy-Dispersive X-ray Spectroscopy (EDX), and zeta potential analysis. UV–Vis spectral analysis exhibited a characteristic absorption peak at 411 nm, confirming the formation of silver nanoparticles. FESEM images revealed predominantly spherical nanoparticles with an average particle size of 33.96 nm. EDX analysis confirmed the presence of elemental silver as the major component, along with minor signals corresponding to organic residues from plant biomolecules. Zeta potential analysis demonstrated a negative surface charge (−26.2 mV), indicating excellent colloidal stability and minimal aggregation. The study highlights the efficiency of *Spondias pinnata* bark extract as a natural reducing and stabilizing agent and supports its potential application in sustainable nanotechnology and biomedical research.

Keywords: Green synthesis, Silver nanoparticles, *Spondias pinnata*, Bark extract, UV–Vis spectroscopy, FESEM, Zeta potential, EDX

1. Introduction

Nanotechnology has emerged as a transformative field with applications spanning medicine, electronics, agriculture, environmental remediation, and materials science. Metallic nanoparticles, particularly silver nanoparticles (AgNPs), have attracted considerable attention due to their unique physicochemical properties, including high surface area, enhanced catalytic activity, optical characteristics, and strong antimicrobial potential.

Conventional synthesis of silver nanoparticles typically involves chemical reduction methods using reducing agents such as sodium borohydride, hydrazine, or citrate. Although effective, these methods often produce hazardous by-products and require stringent reaction conditions. Growing environmental concerns and the need for sustainable manufacturing processes have driven the exploration of eco-friendly alternatives.

Green synthesis of nanoparticles employs biological systems including plant extracts, microorganisms, and biomolecules as reducing and capping agents. Plant-mediated synthesis is particularly advantageous because it is rapid, economical, scalable, and does not require complex sterile conditions. Phytochemicals such as flavonoids, tannins, phenolics, alkaloids, and proteins present in plant extracts play a crucial role in reducing metal ions and stabilizing the resulting nanoparticles.

Spondias pinnata (family: Anacardiaceae) is a medicinal plant widely distributed in tropical and subtropical regions. Traditionally used for its anti-inflammatory, antioxidant, antimicrobial, and therapeutic properties, the bark of *S. pinnata* contains abundant phenolic compounds and tannins, making it a promising candidate for green nanoparticle synthesis. Despite its medicinal significance, limited research has explored the use of *S. pinnata* bark extract for silver nanoparticle synthesis and detailed physicochemical characterization.

The present study aims to synthesize silver nanoparticles using aqueous bark extract of *Spondias pinnata* and to characterize the synthesized nanoparticles using UV–Visible spectroscopy, FESEM, EDX, and zeta potential analysis.

2. Literature Review

Green synthesis of silver nanoparticles (AgNPs) has emerged as a sustainable alternative to conventional chemical methods that often involve toxic reducing agents and high energy requirements (Iravani et al., 2014; Ahmed et al., 2016). Plant-mediated synthesis is particularly advantageous because phytochemicals such as flavonoids, phenolics, terpenoids, and proteins act simultaneously as reducing and capping agents, ensuring eco-friendly and stable nanoparticle formation (Mittal et al., 2013; Singh et al., 2016).

Silver nanoparticles exhibit strong antimicrobial, antioxidant, and catalytic properties, which have led to their application in biomedicine and environmental remediation (Rai et al., 2009; Franci et al., 2015). Characterization techniques such as UV–Visible spectroscopy for surface plasmon resonance, FESEM for morphology, EDX for elemental confirmation, and zeta potential for colloidal stability are widely employed in green synthesis studies (Durán et al., 2016; Slavin et al., 2017).

Although numerous plant species have been explored, limited studies have investigated *Spondias pinnata*, particularly its bark extract, despite its rich phytochemical profile and medicinal significance. Therefore, further exploration of bark-mediated synthesis contributes to sustainable nanotechnology and value addition to medicinal plant resources.

3. Materials and Methods

3.1 Materials

Silver nitrate ($AgNO_3$) of analytical grade was used as a precursor for nanoparticle synthesis. Distilled water was used throughout the experiment. Fresh bark of *Spondias pinnata* was collected from healthy plants and authenticated.

3.2 Preparation of Bark Extract

The collected bark was thoroughly washed with running tap water followed by distilled water to remove debris and contaminants. It was cut into small pieces. Approximately 10 g of powdered bark was boiled in 100 ml distilled water for 20–30 minutes. The extract was cooled and filtered through Whatman No. 1 filter paper. The filtrate was stored at 4 °C until further use.

3.3 Green Synthesis of Silver Nanoparticles

For synthesis, 10 ml of bark extract was added to 90 ml of 1 mM $AgNO_3$ solution under continuous stirring. The reaction mixture was incubated at room temperature. A gradual color change from pale yellow to dark brown indicated nanoparticle formation. The reaction was allowed to proceed for 24 hours to ensure complete reduction of silver ions.

3.4 UV–Visible Spectroscopy

The formation of silver nanoparticles was monitored using a UV–Visible spectrophotometer in the wavelength range of 300–800 nm. The absorption spectrum was recorded at regular intervals.

3.5 FESEM Analysis

The morphology and size distribution of synthesized nanoparticles were analyzed using Field Emission Scanning Electron Microscopy (FESEM). A drop of nanoparticle suspension was placed on a carbon-coated grid and allowed to dry before imaging.

3.6 EDX Analysis

Energy-Dispersive X-ray Spectroscopy (EDX) was performed to determine the elemental composition of the synthesized nanoparticles.

3.7 Zeta Potential Measurement

Zeta potential analysis was carried out using a particle size analyzer to evaluate surface charge and colloidal stability.

4. Results and Discussion

4.1 Visual Observation

The formation of silver nanoparticles was initially confirmed by a distinct color change from light yellow to dark brown. This phenomenon occurs due to surface plasmon resonance (SPR), where conduction electrons on the nanoparticle surface oscillate upon interaction with light.

4.2 UV–Visible Spectral Analysis

The UV–Vis spectrum of the synthesized nanoparticles showed a strong absorption peak at approximately 411 nm. This characteristic SPR peak confirms the formation of silver nanoparticles. The sharp and well-defined peak suggests relatively uniform particle size distribution. Minor shifts in peak position may be attributed to variation in particle size or interaction with phytochemicals.

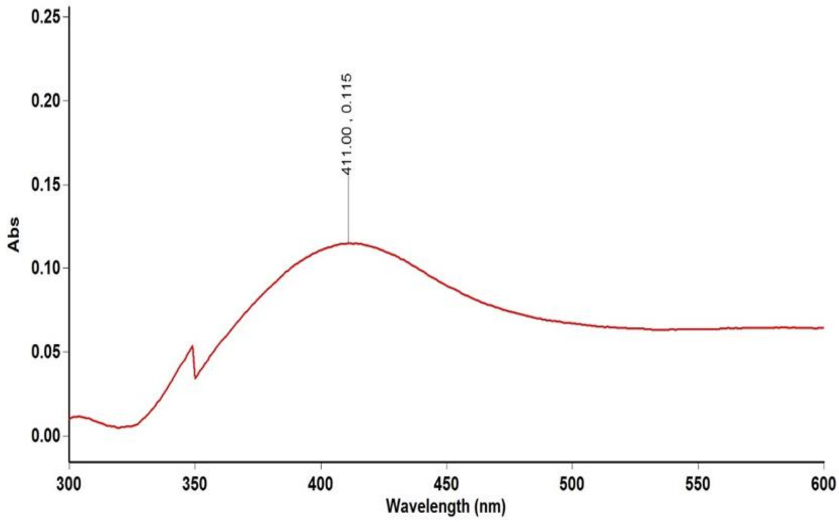


Fig: UV Spectrum of AgNPs of Bark Extract of *Spondias pinnata* (λ_max =411)

4.3 FESEM Analysis

FESEM images revealed that the nanoparticles were predominantly spherical with slight aggregation. The average particle size ranged between 29 and 43 nm. The presence of phytochemical capping agents likely contributed to particle stabilization and prevention of excessive aggregation.

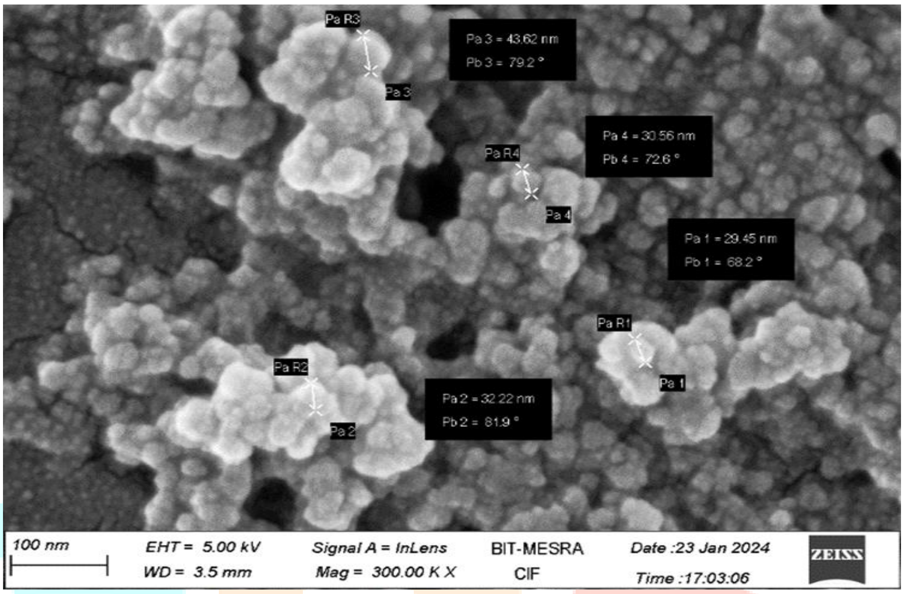


Fig: FESEM Image of Bark-Derived AgNPs at a Magnification of 300.00 KX

4.4 EDX Analysis

EDX spectra showed a strong signal corresponding to silver between 1.3 and 2.6 keV, confirming the elemental composition of the nanoparticles. Additional peaks corresponding to carbon and oxygen were observed, indicating the presence of organic biomolecules adsorbed on the nanoparticle surface.

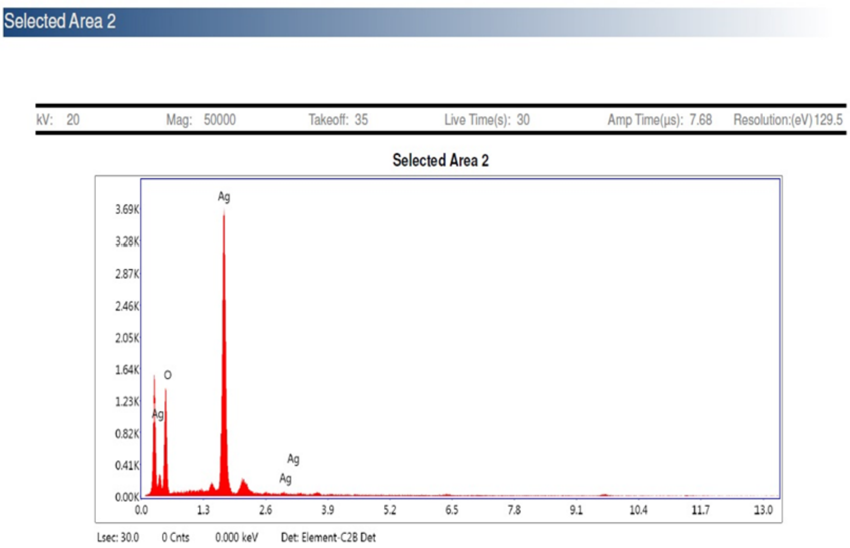
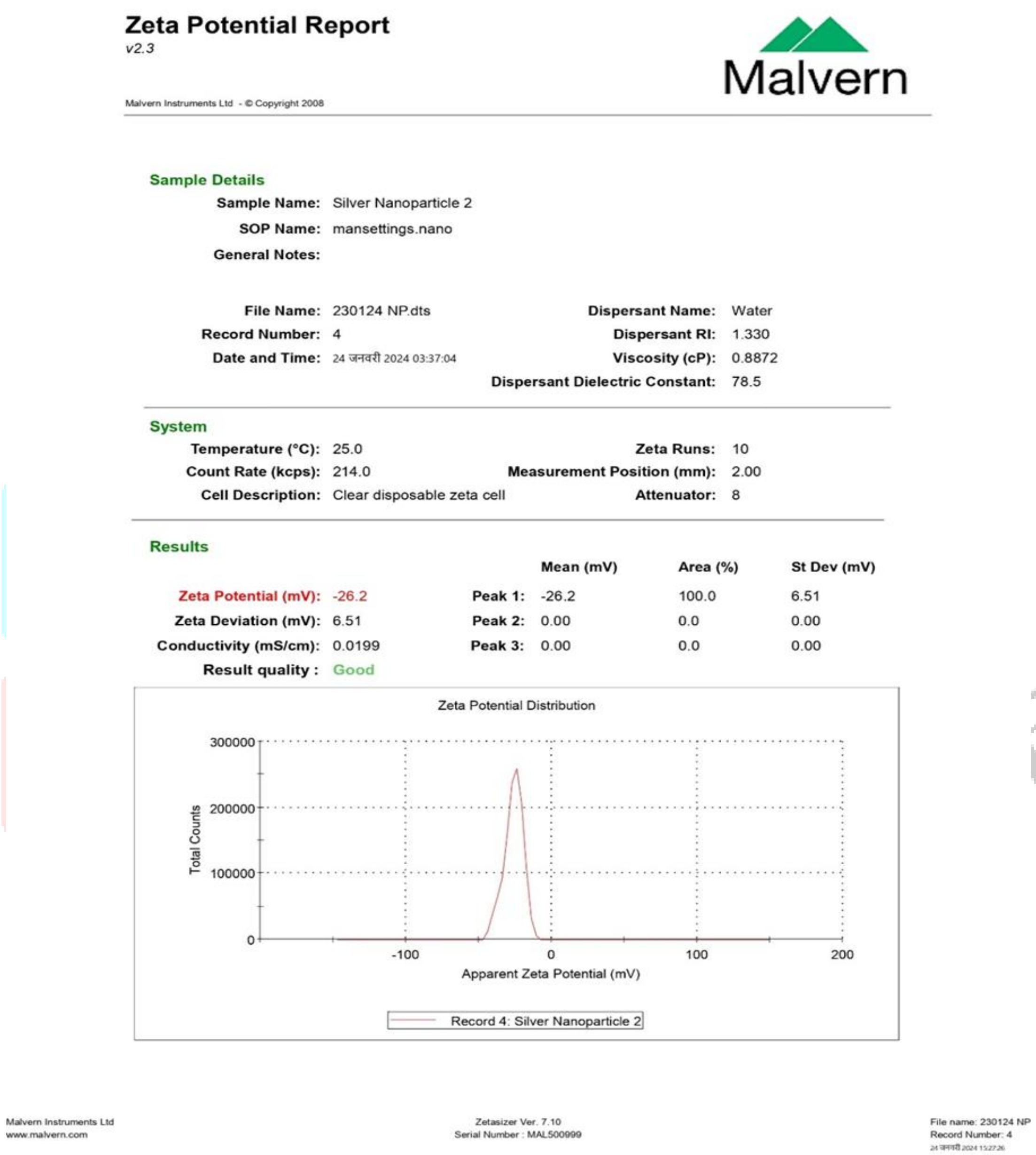


Fig: EDX Report of Bark-Derived AgNPs

4.5 Zeta Potential Analysis

The synthesized AgNPs exhibited a zeta potential value of −26.2 mV. A high negative zeta potential value indicates strong electrostatic repulsion among particles, resulting in excellent colloidal stability. The negative charge may arise from ionized phenolic and carboxyl groups of phytochemicals attached to the nanoparticle surface.


Zeta Potential Report
v2.3

Malvern

Malvern Instruments Ltd - © Copyright 2008

Sample Details

Sample Name: Silver Nanoparticle 2
SOP Name: mansettings.nano
General Notes:

File Name:	230124 NP.dts	Dispersant Name:	Water
Record Number:	4	Dispersant RI:	1.330
Date and Time:	24 जनवरी 2024 03:37:04	Viscosity (cP):	0.8872
		Dispersant Dielectric Constant:	78.5

System

Temperature (°C):	25.0	Zeta Runs:	10
Count Rate (kcps):	214.0	Measurement Position (mm):	2.00
Cell Description:	Clear disposable zeta cell	Attenuator:	8

Results

			Mean (mV)	Area (%)	St Dev (mV)
Zeta Potential (mV):	-26.2	Peak 1:	-26.2	100.0	6.51
Zeta Deviation (mV):	6.51	Peak 2:	0.00	0.0	0.00
Conductivity (mS/cm):	0.0199	Peak 3:	0.00	0.0	0.00
Result quality :	Good				

Malvern Instruments Ltd
www.malvern.com

Zetasizer Ver. 7.10
Serial Number : MAL500999

File name: 230124 NP
Record Number: 4
24 जनवरी 2024 15:27:26

Fig: Zeta Potential Report of Bark-Derived AgNPs

5. Mechanism of Green Synthesis

The green synthesis of silver nanoparticles using *Spondias pinnata* bark extract is primarily driven by phytochemicals such as phenolics, flavonoids, and tannins. These bioactive compounds act as natural reducing agents, converting silver ions (Ag^{+}) from silver nitrate into metallic silver (Ag^{0}) nanoparticles. Simultaneously, functional groups present in the extract bind to the nanoparticle surface, serving as stabilizing and capping agents that prevent aggregation. The reaction typically occurs under ambient conditions, where a visible color change indicates nanoparticle formation due to surface plasmon resonance. This dual role of plant metabolites enables an eco-friendly, cost-effective, and sustainable synthesis process.

6. Conclusion

The present study successfully demonstrates an eco-friendly and efficient method for synthesizing silver nanoparticles using *Spondias pinnata* bark extract. The synthesized nanoparticles were confirmed through UV–Visible spectroscopy, FESEM, EDX, and zeta potential analysis. The nanoparticles exhibited spherical morphology, nanoscale size (29-43 nm), strong silver elemental signals, and excellent colloidal stability. The findings suggest that *Spondias pinnata* bark extract serves as a potent natural reducing and stabilizing agent, supporting sustainable nanotechnology development. Further research focusing on biological evaluation and large-scale production may facilitate practical biomedical applications.

7. Limitations of the Study

- Consistent methodologies and analytical protocols will enable researchers to obtain accurate and comparable results, facilitating the validation of findings and the advancement of knowledge in the field.
- Quantitative phytochemical analysis of *Spondias pinnata* bark extract is necessary for reduction and stabilization.
- Long-term stability studies under different environmental conditions (temperature, pH, ionic strength) for successfully integrating these nanoparticles into commercial applications.
- The synthesis process was conducted only at laboratory scale; scalability, reproducibility, and batch-to-batch consistency is important for various technical, economic, and logistical issues.

Addressing these limitations in future studies would enhance the scientific robustness and application potential of *Spondias pinnata*-mediated silver nanoparticles.

8. References

Ahmed, S., Ahmad, M., Swami, B. L., & Ikram, S. (2016). A review on plants extract mediated synthesis of silver nanoparticles for antimicrobial applications. *Journal of Advanced Research*, *7*(1), 17–28. https://doi.org/10.1016/j.jare.2015.02.007

Akter, M., Sikder, M. T., Rahman, M. M., Ullah, A. K. M. A., Hossain, K. F. B., Banik, S., Hosokawa, T., Saito, T., & Kurasaki, M. (2018). A systematic review on silver nanoparticles-induced toxicity: Physicochemical properties and perspectives. *Journal of Advanced Research, 9,* 1–16. https://doi.org/10.1016/j.jare.2017.10.008

Chowdhury, A., Kunwar, A., & Mandal, S. (2019). Biosynthesized silver nanoparticles as thrombolytic agents: In vitro evaluation. *Biotechnology Reports, 23,* e00363. https://doi.org/10.1016/j.btre.2019.e00363

Durán, N., Durán, M., de Jesus, M. B., Seabra, A. B., Fávaro, W. J., & Nakazato, G. (2016). Silver nanoparticles: A new view on mechanistic aspects on antimicrobial activity. *Nanomedicine: Nanotechnology, Biology and Medicine, 12*(3), 789–799. https://doi.org/10.1016/j.nano.2015.11.016

Fadeel, B., Farcal, L., Hardy, B., Vázquez-Campos, S., Hristozov, D., Marcomini, A., Lynch, I., & Valsami-Jones, E. (2018). Advanced tools for the safety assessment of nanomaterials. *ACS Nano, 12*(11), 10582–10620. https://doi.org/10.1021/acsnano.8b07787

Franci, G., Falanga, A., Galdiero, S., Palomba, L., Rai, M., Morelli, G., & Galdiero, M. (2015). Silver nanoparticles as potential antibacterial agents. *Molecules, 20*(5), 8856–8874. https://doi.org/10.3390/molecules20058856

Gurunathan, S., Han, J. W., Dayem, A. A., Eppakayala, V., & Kim, J. H. (2012). Oxidative stress-mediated antibacterial activity of silver nanoparticles. *International Journal of Nanomedicine, 7*, 5765–5777. https://doi.org/10.2147/IJN.S36867

Iravani, S., Korbekandi, H., Mirmohammadi, S. V., & Zolfaghari, B. (2014). Synthesis of silver nanoparticles: Chemical, physical and biological methods. *Research in Pharmaceutical Sciences, 9*(6), 385–406.

Kalishwaralal, K., BarathManiKanth, S., Pandian, S. R. K., Deepak, V., & Gurunathan, S. (2010). Silver nanoparticles impede the biofilm formation by *Pseudomonas aeruginosa* and *Staphylococcus epidermidis*. *Colloids and Surfaces B: Biointerfaces, 79*(2), 340–344. https://doi.org/10.1016/j.colsurfb.2010.04.014

Khalil, M. M. H., Ismail, E. H., & El-Magdoub, F. (2014). Biosynthesis of silver nanoparticles using olive leaf extract and its antibacterial activity. *Arabian Journal of Chemistry, 7*(6), 1131–1139. https://doi.org/10.1016/j.arabjc.2013.04.007

Mittal, A. K., Chisti, Y., & Banerjee, U. C. (2013). Synthesis of metallic nanoparticles using plant extracts. *Biotechnology Advances, 31*(2), 346–356. https://doi.org/10.1016/j.biotechadv.2013.01.003

Prasad, S., Kumar, R., & Patel, D. K. (2020). Evaluation of thrombolytic activity of green synthesized silver nanoparticles. *Journal of Applied Pharmaceutical Science, 10*(3), 78–84. https://doi.org/10.7324/JAPS.2020.103011

Rai, M., Yadav, A., & Gade, A. (2009). Silver nanoparticles as a new generation of antimicrobials. *Biotechnology Advances, 27*(1), 76–83. https://doi.org/10.1016/j.biotechadv.2008.09.002

Rahman, M. A., Islam, M. S., Haque, P., et al. (2017). In vitro clot lysis activity of plant-mediated silver nanoparticles. *Journal of Thrombosis and Thrombolysis, 44*, 271–279. https://doi.org/10.1007/s11239-017-1531-3

Singh, P., Kim, Y. J., Zhang, D., & Yang, D. C. (2016). Biological synthesis of nanoparticles from plants and microorganisms. *Trends in Biotechnology, 34*(7), 588–599. https://doi.org/10.1016/j.tibtech.2016.02.006

Slavin, Y. N., Asnis, J., Häfeli, U. O., & Bach, H. (2017). Metal nanoparticles: Understanding the mechanisms behind antibacterial activity. *Journal of Nanobiotechnology, 15*, 65. https://doi.org/10.1186/s12951-017-0308-z

Vanlalveni, C., Lallianrawna, S., Biswas, A., Selvaraj, M., Changmai, B., & Rokhum, S. L. (2021). Green synthesis of silver nanoparticles using plant extracts and their antimicrobial activities: A review. *RSC Advances*, *11*, 2804–2837. https://doi.org/10.1039/D0RA09941D