

Green Synthesis of Silver Nanoparticles using Low Molecular Weight Lignin: Optimization, Structural Characterization, and Antibacterial Activity

Munuhe L. N.¹, Madivoli E. S.¹, Lemietaron P. N.¹, Kimani P. K.² and Takai-Yamashita C.^{2,3}

¹Department of Chemistry, Jomo Kenyatta University of Agriculture and Technology P.O Box 62000-00200, Nairobi, Kenya

²Department of Advanced Ceramics Research Centre, Nagoya Institute of Technology, 3-10-1 Honmachi, Tajimi 507-0033, Japan

³Institute of Multidisciplinary Research for Advanced Materials, Tohoku University, 980-8577 Sendai, Miyagi, Japan

INTRODUCTION

Antibacterial resistance is a growing global health challenge that has stimulated the search for alternative antibacterial materials [1]. Silver nanoparticles (AgNPs) exhibit broad-spectrum antibacterial activity with multiple mechanisms of action but are often synthesized using toxic reducing agents such as sodium borohydride [2]. This study explores the use of low molecular weight lignin (LMwLg) derived from the invasive weed *Parthenium hysterophorus* as a sustainable reducing agent for the green synthesis of antibacterial AgNPs.

MAIN OBJECTIVE

To develop a sustainable green synthesis route for silver nanoparticles using low molecular weight lignin (LMwLg) derived from *Parthenium hysterophorus* and evaluate their physicochemical properties and antibacterial activity.

METHODOLOGY

Extraction of lignin from *Parthenium hysterophorus* biomass

Isolation of LMwLg from lignin

Optimization of AgNPs synthesis:

1. AgNO₃ concentration
2. LMwLg concentration
3. Reaction temperature
4. Reaction time

Characterization of synthesized AgNPs:

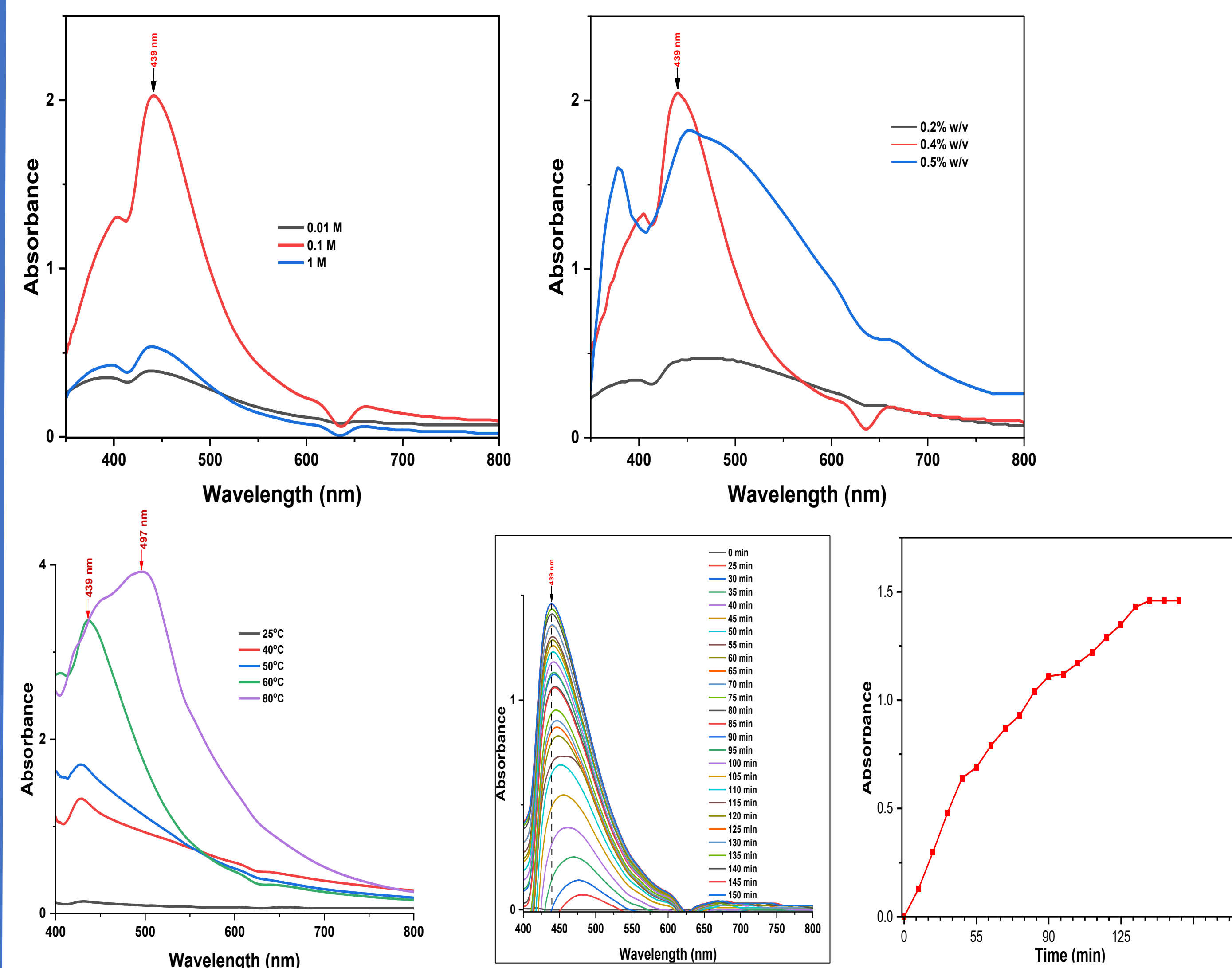
1. UV-Vis
2. FTIR
3. XRD
4. TEM
5. EDX
6. Laser diffraction

Antibacterial activity evaluation:

1. *Staphylococcus aureus*
2. *Streptococcus pyogenes*
3. *Pseudomonas aeruginosa*
4. *Escherichia coli*

RESULTS

SYNTHESIS OPTIMIZATION



ANTIBACTERIAL ACTIVITY

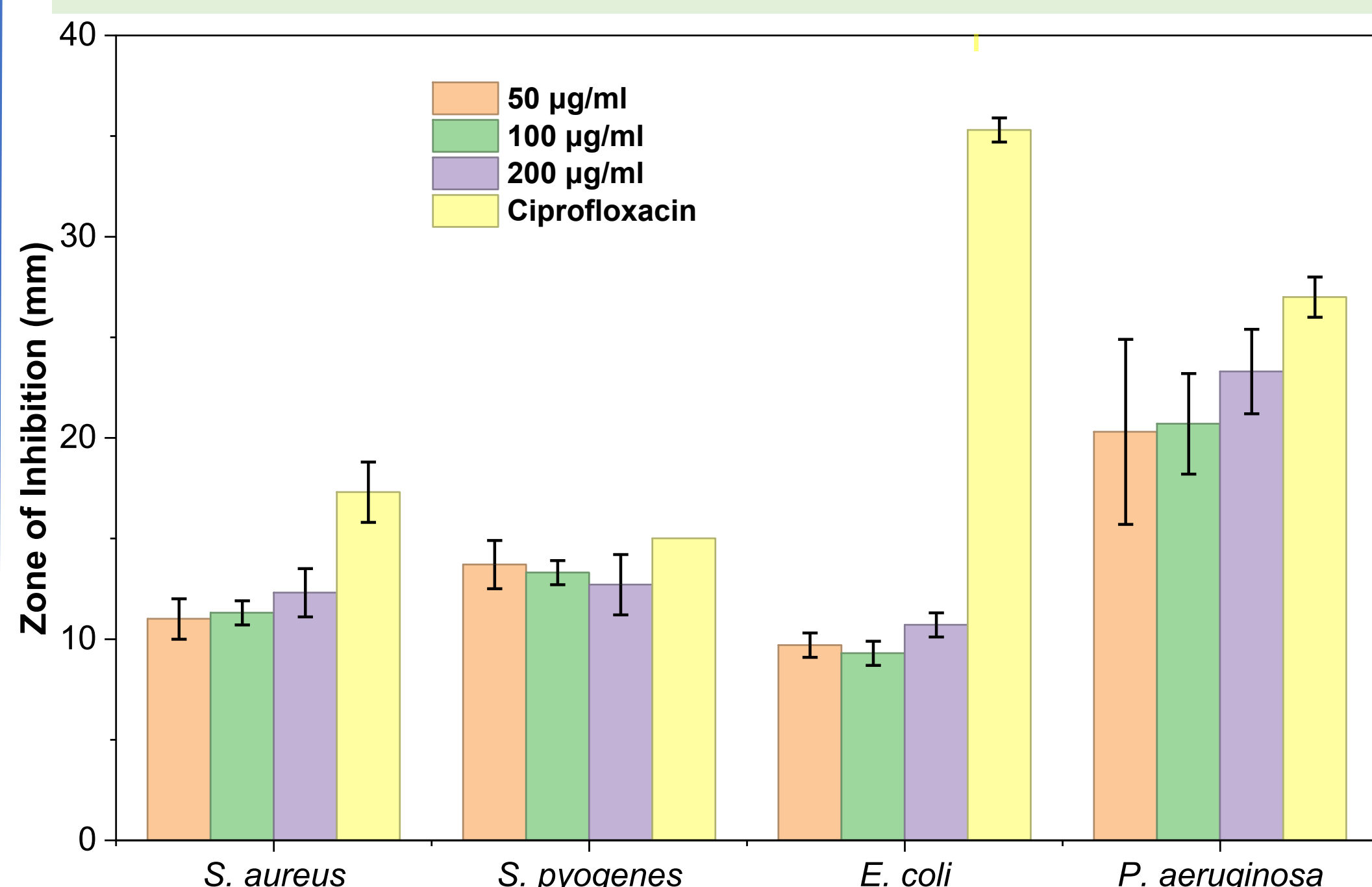
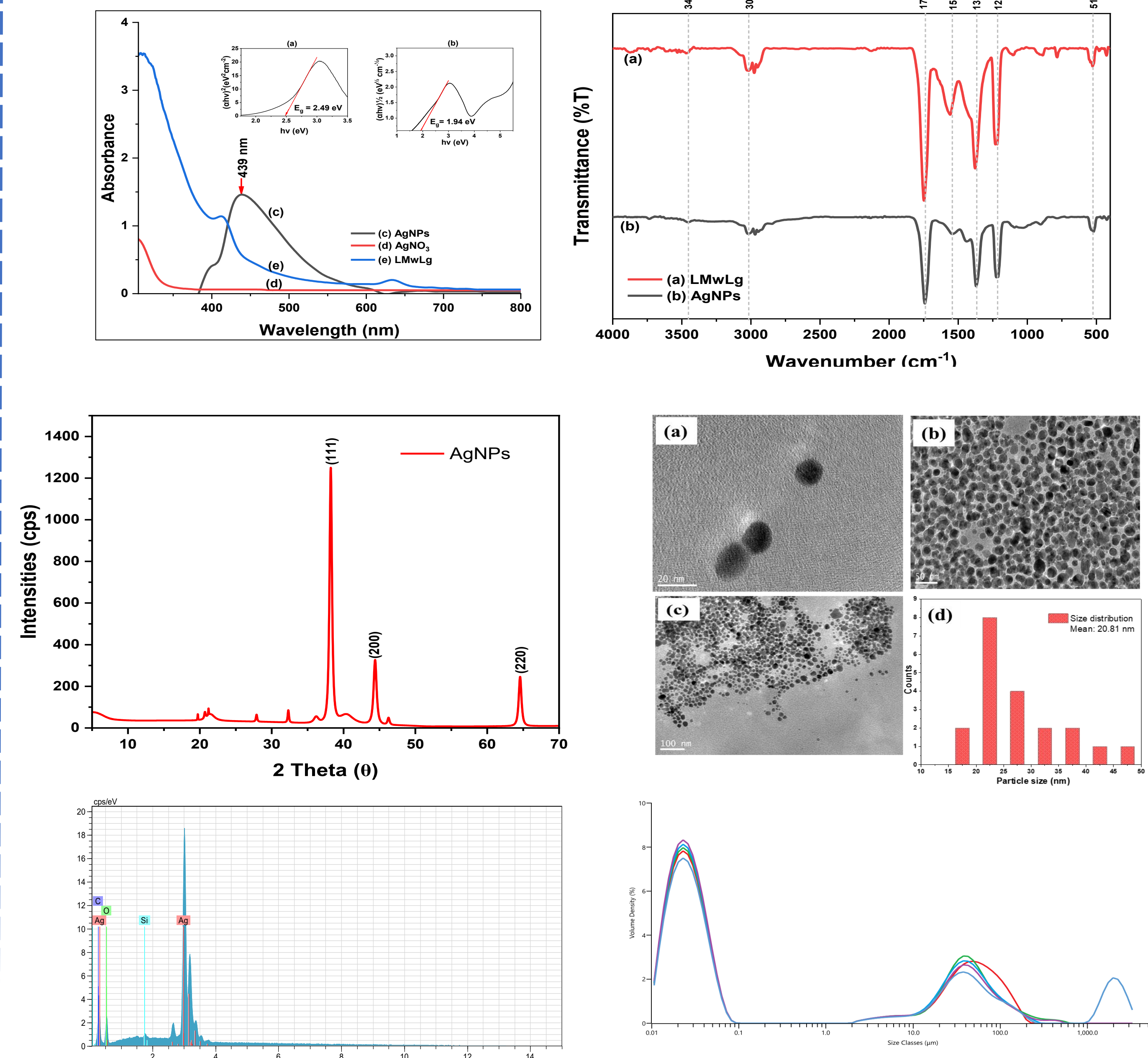


Figure 1: Zone of inhibition of AgNPs against selected bacterial strains. Values are presented as mean $\pm$ SD (n = 3).

CHARACTERIZATION



- Optimization of synthesis conditions (0.1 M, 0.4% w/v, 60 °C, and 140 min) yielded spherical and crystalline AgNPs with an average size of approximately 20 nm.
- LMwLg-mediated AgNPs exhibited antibacterial activity against all tested bacterial strains. The strongest inhibition was observed against *P. aeruginosa* (23.3 mm), while *E. coli* was the least susceptible (9.3 mm).
- No inhibition was observed for the negative control, confirming that the antibacterial activity originated from the synthesized AgNPs.

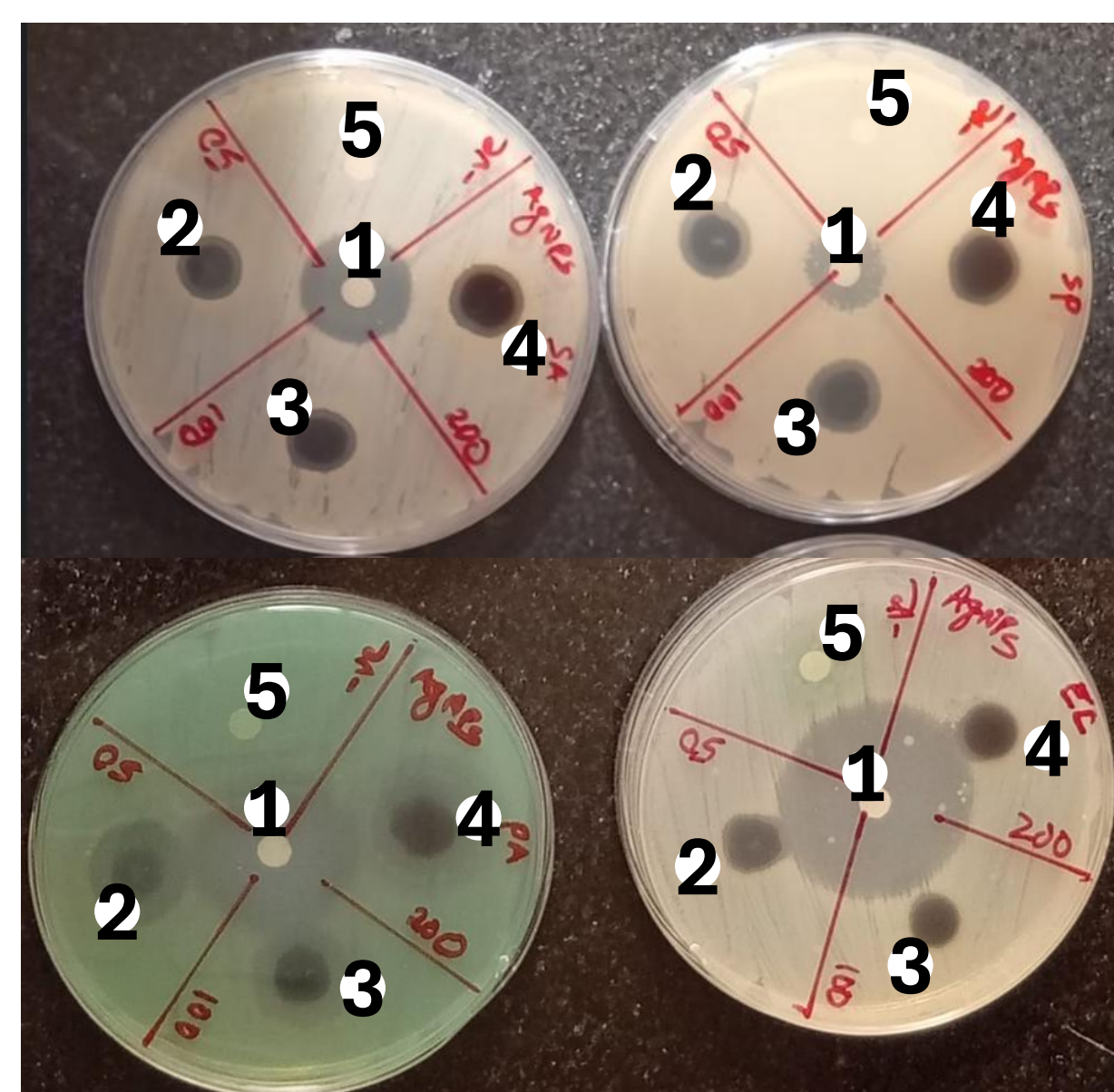


Figure 2: Representative agar diffusion plates showing inhibition zones produced by AgNPs against selected bacterial strains.

CONCLUSION

- LMwLg derived from *Parthenium hysterophorus* was successfully utilized as a reducing agent for the synthesis of AgNPs.
- Synthesis parameters influenced AgNPs formation as indicated by changes in SPR band.
- AgNPs exhibited antibacterial activity against both Gram-positive and Gram-negative bacteria, demonstrating their potential as sustainable antibacterial materials.
- These findings highlight the value of invasive biomass utilization in development of antibacterial nanomaterials.

FUTURE DIRECTION

- Determine the minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) of the synthesized AgNPs.
- Investigate the antibacterial mechanism of action of LMwLg-mediated AgNPs.

REFERENCES

1. Nazir, A., Nazir, A., Zuhair, V., Aman, S., Sadiq, S. U. R., Hasan, A. H., ... & Bulimbe, D. B. (2025). The global challenge of antimicrobial resistance: mechanisms, case studies, and mitigation approaches. *Health Science Reports*, 8(7), e71077.
2. Asif, M., Yasmin, R., Asif, R., Ambreen, A., Mustafa, M., & Umbreen, S. (2022). Green synthesis of silver nanoparticles (AgNPs), structural characterization, and their antibacterial potential. *Dose-response*, 20(2), 15593258221088709.

ACKNOWLEDGEMENT

AFRICA-ai-JAPAN

UNIVERSITY OF JYVÄSKYLÄ

岐阜大学
GIFU UNIVERSITY