JMMS

Journal of Material and Metamaterial Sciences

Vol. 1, No. 1, January 2025, pp. 13-20, DOI: 10.59190/jmms.v1i1.294

PUBLISHED BY

LSPRAR

Biosynthesis and characterisation of silver nanoparticles utilising tin (*Ficus carica*) leaf extracts: A review

Dinda Pratiwi

Department of Physics, Universitas Riau, Pekanbaru 28293, Indonesia

ABSTRACT

Silver nanoparticles (AgNPs) are materials with various potential applications, ranging from catalysts to antibacterial agents. This study aims to synthesize and characterize AgNPs using tin leaf extract (*Ficus carica*) as a bioreduction agent in a green synthesis method. The synthesis process was carried out by utilizing $AgNO_3$ as a precursor and evaluated using UV-Vis spectroscopy, X-ray diffraction (XRD), and scanning transmission electron microscopy (STEM). UV-Vis results showed a characteristic absorption peak at a wavelength of 419 nm, indicating the successful synthesis of AgNPs. XRD analysis identified a face-centered cubic structure with an average particle size of 22.6 nm. STEM revealed a spherical particle morphology with sizes ranging from 11.97 – 20.31 nm. This green synthesis approach provides an environmentally friendly, efficient, and cost-effective solution in the production of AgNPs, with broad potential applications in the medical and technological fields.

ARTICLE INFO

Article history:

Received Nov 11, 2024
Revised Dec 14, 2024
Accepted Jan 17, 2025

Keywords:

Ficus carica
Green Synthesis
Silver Nanoparticles
UV-Vis Spectroscopy
X-Ray Diffraction

* **Corresponding Author**
E-mail address: dinda.pratiwi2489@student.unri.ac.id

1. INTRODUCTION

Nanoscience and nanotechnology involve the examination of the properties of things and structures within a minuscule scale ranging from approximately 1 nanometre (10^{-9} m) to 100 nanometres (100×10^{-9} m = 10^{-7} m). The name "nano" originates from the Greek word for "dwarf." The nanometre is a unit of length equivalent to one billionth of a metre, or 1/1,000,000,000 meters. A nanometre corresponds to the length of a sequence of 10 hydrogen atoms, representing a very small dimension. The development period of nanotechnology, or the engineering of substances at the nanometre scale (one billionth of a metre), has been rather brief. The advancement of nanoparticles in Indonesia commenced about in 2000. Subsequently, its diverse applications emerged. Professor Nario Taniguchi of Tokyo Science University initially invented the word "nanoparticle" in 1940. He commenced research on the process of synthesising nanoparticles from quartz crystals, silicon, and alumina ceramics utilising ultrasonic machines [1].

Nanoparticles have undergone extensive research in recent decades owing to their diverse potential applications, spanning from medicine to industrial technologies. Nevertheless, despite their potential advantages, significant concerns exist regarding the safety implications of nanoparticle usage and exposure. Numerous factors affect the toxicity of nanoparticles, such as size, shape, content, and surface chemistry. The little size of nanoparticles enables them to traverse cell membranes and access intracellular regions inaccessible to larger particles. The morphology of the nanoparticle significantly influences its toxicity; for instance, nanoparticles exhibit more toxicity than spherical counterparts due to their increased surface area. The chemical composition and surface modification influence the interaction of nanoparticles with biomolecules in the body [2].

Silver nanoparticles (AgNPs) are often synthesised by physical and chemical processes; however, these approaches have numerous drawbacks, such as the utilisation of hazardous substances that may lead to environmental contamination, generate poisonous by-products, and necessitate substantial energy consumption [3]. Nanomaterials can be synthesised by physical, chemical, or environmentally friendly processes. Physical methods, specifically inert gas condensation, physical vapour deposition, laser and flame spray pyrolysis, electro-spraying processes, and melt mixing, are costly and necessitate high-throughput equipment. Chemical procedures such as sol-gel synthesis, microemulsion techniques, hydrothermal synthesis, polyol synthesis, and plasma-enhanced vapour deposition utilise chemicals that generate toxic byproducts detrimental to human health or the environment. Nonetheless, green synthesis methods provide an eco-friendly, economical, and efficient approach to the synthesis of nanomaterials. It is undergoing rigorous examination as a substitute for traditional synthesis [4].

Moreover, traditional synthesis methods utilising chemicals are increasingly becoming problematic for Green synthesis methods utilising natural resources for the production of AgNPs represent a prudent choice for environmental and human health considerations. Green synthesis minimises the use of deleterious substances.

The influence of chemicals on the environment can be mitigated by utilising natural elements, including plant extracts, microbes, or other organic substances. The primary objectives of green synthesis are to generate products that are safer for the environment and human health, minimise hazardous waste, and enhance the efficiency of energy and resource utilisation. For instance, green synthesis may utilise natural plant components to generate nanoparticles in a more environmentally friendly and less harmful manner. This strategy is becoming increasingly significant as awareness of environmental preservation grows.

The tin leaf (*Ficus carica*) has garnered interest in contemporary science due to its diverse array of advantageous active components, including flavonoids, phenols, and other antioxidants. In nanotechnology, tin leaf extract is utilised as a natural reducing agent in the synthesis of AgNPs. This process aligns with green synthesis, which use natural substances to generate nanoparticles without the incorporation of toxic chemicals. This technique mitigates environmental concerns while also providing the opportunity to generate safe and effective AgNPs. Due to their high phytochemical content, tin fruit leaves are a viable option for the ecologically friendly and cost-effective synthesis of AgNPs.

A green synthesis procedure employing tin leaves can diminish the reliance on hazardous chemicals typically utilised in traditional synthesis processes. Utilising tin leaf extract facilitates the production of Ag-NPs with a reduced carbon footprint and diminished environmental pollution risk. This methodology endorses the principle of sustainability by producing items that are both efficient in functionality and environmentally safe.

This work examines the synthesis of AgNPs utilising tin leaf as a bioreductant and $AgNO_3$ as the silver precursor. At a concentration of 0.01 mol for 24 hours at 50°C. The synthesised AgNPs were evaluated for their optical characteristics, structure, and shape by UV-Vis spectroscopy, X-ray diffraction (XRD), and scanning transmission electron microscopy (STEM).

2. THEORITICAL REVIEW

2.1. Theory of AgNPs

AgNPs are stable particles measuring 1-100 nm in size, with potential use as catalysts, optical sensor detectors, and antibacterial agents [5]. The antibacterial efficacy of AgNPs is affected by the physical attributes of nanoparticles, including size, shape, and surface features [6].

2.2. Synthesis Method for AgNPs

Synthesis is the process of creating or amalgamating many components to produce something novel or more intricate. Synthesis in chemistry denotes the formation of chemical compounds from more fundamental substances or smaller constituents. The process entails several chemical reactions, both naturally occurring and intentionally induced, to generate compounds with specified characteristics.

2.3. UV-Vis Spectroscopy

UV-Vis spectroscopy is an analytical method employed to quantify the absorption of light within the UV and visible light wavelength ranges. The fundamental premise of this approach is that as light traverses a sample, the molecules inside the sample can absorb photons of suitable energy, resulting in the movement of electrons from lower to higher energy states. This procedure yields an absorption spectrum that conveys information regarding the structure and chemical properties of the analysed molecule. A primary advantage of UV-Vis spectroscopy is its capacity to deliver rapid and quantitative data, along with a linear correlation between light absorption and chemical concentration.

2.4. XRD

XRD is a method employed to analyse the crystalline structure of a material through the application of X-rays. When X-rays interact with a crystalline substance, a portion of them is reflected in a distinct pattern, contingent upon the atomic arrangement within the crystal. The diffraction process transpires as a result of the interaction between X-rays and the atomic planes within the material. Analysing the produced patterns allows for the extraction of information regarding the internal structure, including the crystal type, atomic spacing, and the regularity of atomic arrangement inside the material. XRD is highly effective for material identification and the investigation of material characteristics.

2.5. STEM

STEM is an imaging technique that employs electron beams to generate high-resolution pictures of object surfaces. This approach involves accelerating an electron beam and directing it towards the sample, resulting in interactions with surface atoms that generate signals, including secondary electrons and scattering. The signals are examined to produce a distinct image. Scanning electron microscopy (SEM) offers superior resolution images relative to light microscopy, facilitating the examination of structures at microscopic to nanoscale dimensions. The approach also yields significant insights on the morphology and chemical composition of the sample surface.

2.6. *Ficus carica* folium

The leaves of Ficus carica possess numerous bioactive chemicals that can be isolated for the manufacture of AgNPs. One of the primary components is flavonoids. These flavonoids can convert silver ions (Ag^+) to AgNPs while also stabilising the resultant nanoparticles. Furthermore, tin leaves are abundant in polyphenols, which serve as reducing and stabilising agents, inhibiting nanoparticle aggregation. A notable component is carboxylic acid, which can engage with Ag^+, promoting reduction and ensuring nanoparticle stability. The amino acid composition in the leaves additionally aids in the development of a protective coating encasing the nanoparticles.

2.7. Bioreduction

Bioreduction is a process wherein metal ions, such as Ag^+, are transformed into AgNPs through the assistance of natural chemicals derived from plants. The leaf extract of Ficus carica is employed to bioreduce Ag^+ into nanoparticle form. The bioreduction technique utilises Ficus carica leaf extract as a reducing agent, which contains natural chemicals capable of donating electrons to Ag^+. These substances are often plant secondary metabolites, including flavonoids, polyphenols, and terpenoids, which possess the capability to decrease metal ions to their metallic state, specifically AgNPs (Ag^0). As demonstrated in the subsequent reaction is $Ag^+ + e^- \rightarrow Ag^{(0)}$.

3. RESEARCH METHODS

3.1. Examination of Test Outcomes from UV-Vis Spectroscopy

UV-Vis examination yields insights into the properties of the synthesised nanoparticles. AgNPs exhibit a characteristic absorption peak within the 400 – 450 nm region. This peak arises from the surface plasmon phenomenon, wherein electrons on the nanoparticle surface oscillate in reaction to light. Upon the introduction of Ficus carica leaf extract into a Ag^+ solution, a reduction reaction transpires, converting Ag^+ to Ag^0 and resulting in the formation of AgNPs.

Alterations in the UV-Vis spectrum can be detected during synthesis. Initially, in the presence of Ag^+, no absorption peak will be observed in that range. Nonetheless, the emergence of absorption peaks over time signifies the creation of nanoparticles. A more pronounced peak signifies a rise in the concentration of AgNPs generated. The peak's intensity and width can be utilised to assess the reaction time.

3.2. Examination of Test Outcomes from XRD

The structural investigation of Ag-NPs was conducted using a Panalytical Empyrean Advance model X-ray diffractometer. XRD analysis was employed to qualitatively ascertain the sample's crystallinity, isomorphic substitution, and chemical composition. Despite the simplicity of the green synthesis approach, the product yield was minimal. Consequently, the experiment was conducted a minimum of four times to acquire sufficient product for all analyses. Identical synthesis conditions were employed in each iteration, yielding consistent results in the UV-Vis and XRD analyses.

3.3. Examination of Test Outcomes from STEM

The surface morphology, dimensional characteristics, and form of AgNPs were examined using STEM microscopy. Similar to UV-Vis analysis, STEM analysis is among the most prevalent methods for characterising nanoparticles.

4. RESULTS AND DISCUSSIONS

4.1. Evaluation of Test Outcomes from UV-Vis Spectroscopy

The UV-Vis absorption spectra depicted in this picture demonstrate the properties of AgNPs synthesised via the biogenic method. The horizontal axis of the graph represents the wavelength in nanometres (nm), and the vertical axis indicates the absorbance level. The UV-Vis absorption spectra are helpful in detecting AgNPs and offer insights into their size and distribution inside the sample.

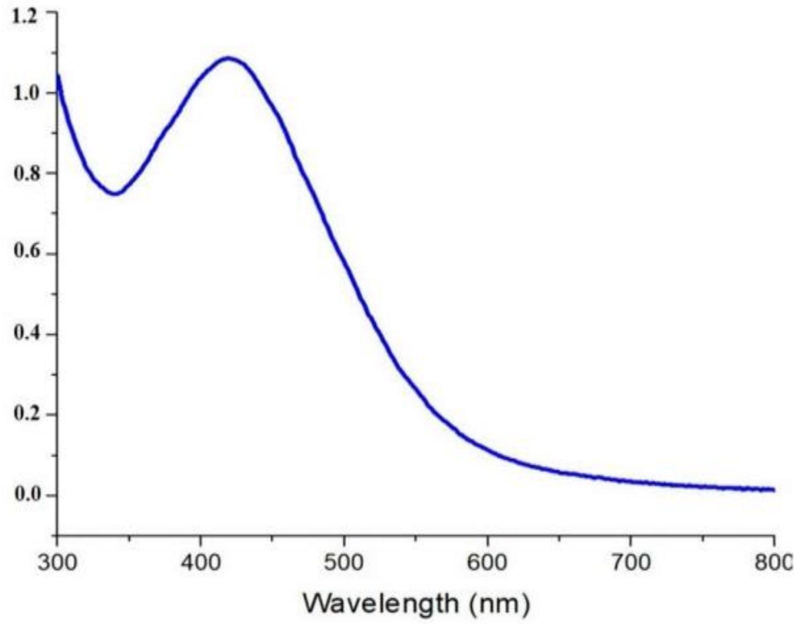

Figure 1. UV-Vis absorption spectra of AgNPs derived from *Ficus carica* leaf extract.

In this spectrum, a significant absorbance peak is observed at approximately 400 nm. This peak is characteristic of well-structured and stable AgNPs, referred to as surface plasmon resonance.

This resonance transpires when surface electrons of the nanoparticles vibrate collectively in reaction to light exposure at a certain wavelength. This occurrence verifies the existence of AgNPs in the sample, as these wavelengths are strongly associated with the characteristic optical properties of AgNPs. Following the principal peak at approximately 419 nm, the graph exhibits a progressive decline in absorbance at extended wavelengths, ranging from roughly 500 – 800 nm. This reduction signifies the absence of substantial surface plasmon resonance within that wavelength range. This reinforces the conclusion that the AgNPs in the sample exclusively demonstrate significant plasmonic activity at a wavelength of 400 nm, consistent with their inherent properties.

4.2. Evaluation of Test Outcomes from XRD

The crystalline properties of the synthesised powder materials were examined using XRD. Figure 2 illustrates the XRD model of the AgNPs synthesised utilising *Ficus carica* leaf extract. A sequence of distinct diffraction peaks was detected, corresponding to five principal peak planes at angles of 32.47°, 38.27°, 54.98°, 64.69°, and 67.80°. The spectra associated with (111), (200), (220), (311), and (222) align with the cubic phase structure and relate to JCPDS card number: (01-076-1393). The Debye-Scherrer equation is employed to determine the average particle size.

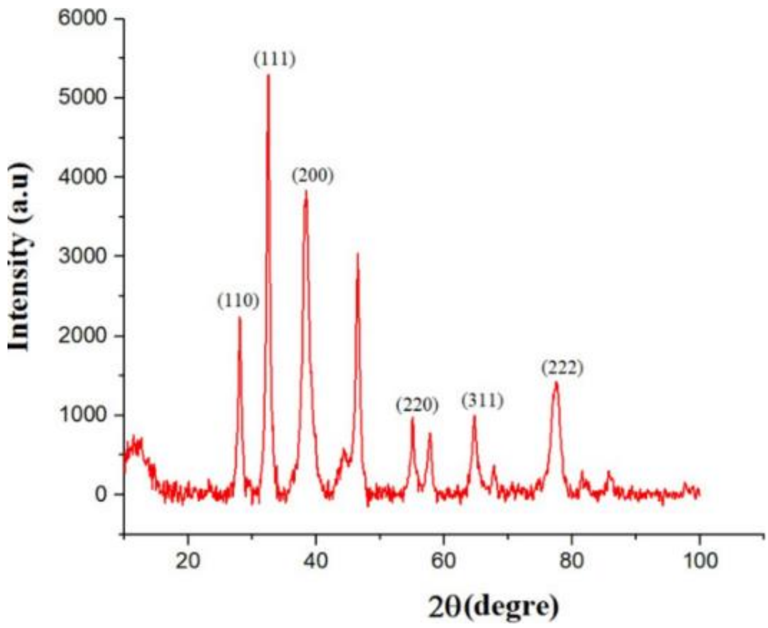

Figure 2. XRD spectra of AgNPs derived from *Ficus carica* leaf extract.

The particle size is represented by D, the X-ray wavelength is shown as λ, θ is the Bragg angle, β is half the height of the XRD peak, and k is the form factor constant (k = 0.9). The mean particle size of Ag-NPs, calculated using the Debye-Scherrer formula, is around 22.6 nm. Several prior investigations have indicated the synthesis of smaller Ag-NPs compared to those produced in this investigation [7, 8], whilst others have reported sizes comparable to those observed here [9-12]. Despite the simplicity of the green synthesis approach, the product yield was minimal. Consequently, the experiment was conducted a minimum of four times to acquire sufficient product for all analyses. The identical synthesis conditions were maintained in each iteration, yielding consistent results in the UV-Vis and XRD analyses. This is crucial for the experiment's repeatability.

4.3. Examination of Test Outcomes from STEM

In STEM analysis, high-resolution images can be acquired if the sample material is adequately disseminated prior to examination. Figure 3 exemplifies this remarkably. Upon examination of the structure and morphology of the non-agglomerated AgNPs, it is observed that the nanoparticles exhibit a spherical shape. STEM pictures of AgNPs captured at 500 times magnification reveal silver particle sizes ranging from 11.97 – 20.31 nm. Table 1 presents AgNPs of comparable form and size synthesised from various plants as documented in the literature.

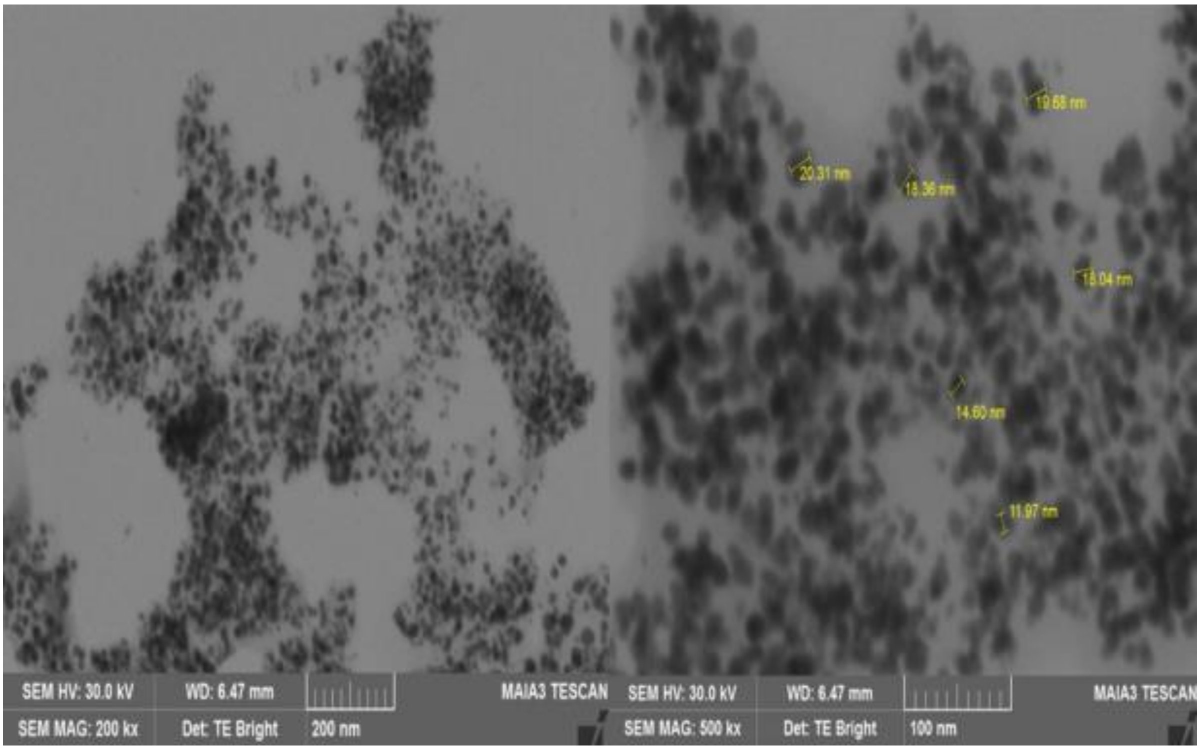

Figure 3. STEM picture depicting AgNPs derived from *Ficus carica* leaf extract.

Table 1. Diverse flora employed in the synthesis of green AgNPs, together with the morphology and dimensions of the resultant nanoparticles.

Plants	Dimensions and morphology	References
Momordica charantia	Spherical; 11 – 16 nm	[13]
Camellia sinensis	Spherical; 20 nm	[14]
Raphanus sativus	Spherical; 6 – 38 nm	[15]
Prunus yedoensis	Spherical, oval; 18 – 20 nm	[16]
Ziziphus oenoplia	Spherical; 10 nm	[17]
Sesbania grandiflora	Spherical; 20 nm	[18]
Talinum triangulare	Spherical; 13.86 nm	[19]
Ligustrum lucidum	Spherical; 13 nm	[20]
Melaleuca alternifolia	Spherical; 11.56 nm	[21]
Mikania micrantha	Spherical; 10 – 20 nm	[22]

5. CONCLU SION

The manufacture of AgNPs utilising natural resources, particularly *Ficus carica* leaf extract, has effectively yielded environmentally benign and economical nanoparticles. UV-Vis spectroscopy validated the synthesis of AgNPs, distinguished by peak absorbance at the maximum wavelength of 419 nm. XRD examination demonstrated that the nanoparticles have a face-centered cubic (FCC) shape, as evidenced by peaks corresponding to Miller indices (110), (111), (200), (220), (311), and (222). Additionally, STEM analysis revealed that the AgNPs are non-agglomerated, possess a spherical morphology, and have diameters between 11.97 and 20.31 nm.

REFERENCES

[1] Fahmi, M. Z. (2019). *Nano teknologi dalam perspektif kesehatan*. Airlangga University Press: Surabaya.

[2] Kurniawan, W. (2024). *Nanoteknologi untuk kesehatan*. CV. Sakti: Banyumas.
[3] Xu, L., Wang, Y. Y., Huang, J., Chen, C. Y., Wang, Z. X., & Xie, H. (2020). Silver nanoparticles: Synthesis, medical applications and biosafety. *Theranostics*, **10**(20), 8998–9031.
[4] Effendi, M. (2021). *Monograf nanopartikel zinc oxide propolis sebagai liner untuk proteksi pulpa gigi terhadap bakteri Streptococcus mutans*. UMM Press: Malang.
[5] Cheviron, P., Gouanvé, F., & Espuche, E. (2016). Preparation, characterization and barrier properties of silver/montmorillonite/starch nanocomposite films. *Journal of Membrane Science*, **497**, 162–171.
[6] Chuchita, C. (2018). Sintesis nanopartikel dari perak nitrat dengan tirosin sebagai reduktor dan agen pengkaping untuk membentuk nanokomposit film AgNPs-poli asam laktat sebagai antibakteri. *BIMIPA*, **25**(2), 140–153.
[7] Namasivayam, S. K. R. & Chitrakala, K. (2011). Ecotoxicological effect of *Lecanicillium lecanii* (Ascomycota: Hypocreales) based silver nanoparticles on growth parameters of economically important plants. *Journal of Biopesticides*, **4**(1), 97.
[8] 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.
[9] Jo, Y. K., Kim, B. H., & Jung, G. (2009). Antifungal activity of silver ions and nanoparticles on phytopathogenic fungi. *Plant disease*, **93**(10), 1037–1043.
[10] Korkmaz, S., Cetin, M. H., Dogan, S., Ozen, K., Ayhan, E., Ozgul, M., & Ozdemir, S. F. (2020). A Comprehensive investigation on tribological performance of nano-silver and nano-gold additivated fluids on wearing surfaces. *Journal of Tribology*, **142**(8), 082101.
[11] Korkmaz, N., Ceylan, Y., Taslimi, P., Karadağ, A., Bülbül, A. S., & Şen, F. (2020). Biogenic nano silver: synthesis, characterization, antibacterial, antibiofilms, and enzymatic activity. *Advanced Powder Technology*, **31**(7), 2942–2950.
[12] Ivask, A., ElBadawy, A., Kaweeteerawat, C., Boren, D., Fischer, H., Ji, Z., Chang, C. H., Liu, R., Tolaymat, T., Telesca, D., Zink, J. I., Cohen, Y., Holden, P. A., & Godwin, H. A. (2014). Toxicity mechanisms in Escherichia coli vary for silver nanoparticles and differ from ionic silver. *ACS nano*, **8**(1), 374–386.
[13] Ajitha, B., Reddy, Y. A. K., & Reddy, P. S. (2015). Biosynthesis of silver nanoparticles using Momordica charantia leaf broth: evaluation of their innate antimicrobial and catalytic activities. *Journal of Photochemistry and Photobiology B: Biology*, **146**, 1–9.
[14] Goswami, S. R., Sahareen, T., Singh, M., & Kumar, S. (2015). Role of biogenic silver nanoparticles in disruption of cell–cell adhesion in Staphylococcus aureus and Escherichia coli biofilm. *Journal of Industrial and Engineering Chemistry*, **26**, 73–80.
[15] 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 of recent literature. *RSC advances*, **11**(5), 2804–2837.
[16] Velmurugan, P., Cho, M., Lim, S. S., Seo, S. K., Myung, H., Bang, K. S., Sivakumar, S., Cho, K. M., & Oh, B. T. (2015). Phytosynthesis of silver nanoparticles by Prunus yedoensis leaf extract and their antimicrobial activity. *Materials Letters*, **138**, 272–275.
[17] Soman, S. & Ray, J. G. (2016). Silver nanoparticles synthesized using aqueous leaf extract of Ziziphus oenoplia (L.) Mill: characterization and assessment of antibacterial activity. *Journal of Photochemistry and Photobiology B: Biology*, **163**, 391–402.
[18] Ajitha, B., Reddy, Y. A. K., Rajesh, K. M., & Reddy, P. S. (2016). Sesbania grandiflora leaf extract assisted green synthesis of silver nanoparticles: Antimicrobial activity. *Materials Today: Proceedings*, **3**(6), 1977–1984.
[19] Elemike, E. E., Onwudiwe, D. C., Fayemi, O. E., Ekennia, A. C., Ebenso, E. E., & Tiedt, L. R. (2017). Biosynthesis, electrochemical, antimicrobial and antioxidant studies of silver nanoparticles mediated by Talinum triangulare aqueous leaf extract. *Journal of Cluster Science*, **28**, 309–330.
[20] Huang, W., Yan, M., Duan, H., Bi, Y., Cheng, X., & Yu, H. (2020). Synergistic antifungal activity of green synthesized silver nanoparticles and epoxiconazole against Setosphaeria turcica. *Journal of Nanomaterials*, **2020**(1), 9535432.

[21] Ramadan, M. A., Shawkey, A. E., Rabeh, M. A., & Abdellatif, A. O. (2020). Promising antimicrobial activities of oil and silver nanoparticles obtained from Melaleuca alternifolia leaves against selected skin-infecting pathogens. *Journal of herbal medicine*, **20**, 100289.
[22] Biswas, A., Vanlalveni, C., Adhikari, P. P., Lalfakzuala, R., & Rokhum, L. (2019). Biosynthesis, characterisation and antibacterial activity of Mikania micrantha leaf extract-mediated AgNPs. *Micro & Nano Letters*, **14**(7), 799–803.