

Phyto-amalgamation of silver nanoparticle using methanolic extract of *Bauhinia acuminata*

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ABSTRACT

Nanotechnology is a rapidly evolving interdisciplinary field, and silver nanoparticles (AgNPs) are among the most extensively studied nanomaterials due to their unique properties and wide-ranging applications. This study focuses on the green synthesis of silver nanoparticles using the methanolic extract of *Bauhinia acuminata*, a plant known for its rich phytochemical content. The objectives include synthesizing AgNPs, characterizing their size, shape, and properties using various analytical techniques, and evaluating their biological activities. UV-Vis spectroscopy, scanning electron microscopy (SEM), X-ray diffraction (XRD), and Fourier transform infrared spectroscopy (FTIR) were employed to analyze the synthesized nanoparticles. The results indicate that the nanoparticles have a uniform size distribution, are well-dispersed, and exhibit the characteristic features of silver nanoparticles. The study demonstrates that the phytochemicals in *Bauhinia acuminata* act as reducing and stabilizing agents, making this green synthesis method eco-friendly and sustainable. The synthesized AgNPs show potential for various applications, including antimicrobial, antioxidant, and anti-inflammatory activities, highlighting the value of *Bauhinia acuminata* in nanotechnology.

Key Words - *Bauhinia acuminata*, Nanoparticles, Antimicrobial, Anti-inflammatory

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INTRODUCTION

Nanotechnology is an emerging interdisciplinary field, particularly significant in biotechnology, due to its potential to revolutionize various scientific and industrial applications. Among the various types of nanomaterials, silver nanoparticles (AgNPs) are extensively studied for their unique properties and broad range of applications, including in antimicrobial agents, diagnostics, water purification, and more. Traditional chemical and physical methods for synthesizing silver nanoparticles are often expensive and environmentally unfriendly. Consequently, there

has been a growing interest in developing biological synthesis methods that are more sustainable and cost-effective.

Biosynthesis of silver nanoparticles, often referred to as 'green synthesis,' employs natural resources such as plant extracts, which act as reducing and capping agents. This method is advantageous because it is environmentally benign, non-toxic, and utilizes renewable resources. Plants, in particular, are a rich source of secondary metabolites, which are effective in reducing metal ions and stabilizing nanoparticles. Medicinal plants have been used for

centuries in traditional medicine and are now gaining attention for their potential in nanotechnology.

Bauhinia acuminata, commonly known as the Dwarf White *Bauhinia*, belongs to the family Caesalpiniaceae and is native to Asia. This plant, which can grow up to 3 meters in height, is characterized by its white, fragrant flowers that bloom in spring, often referred to as the Snowy Orchid Tree. The leaves of *Bauhinia acuminata* are shaped like a cow's hoof. The plant is known for its rich phytochemical content, including flavonoids, alkaloids, glycosides, saponins, tannins, and steroids (Dongray *et al.*, 2016). Traditional uses of *Bauhinia acuminata* in Indian medicine include treating biliousness, while in Malaysia and Indonesia, it is used to treat common cold and cough (Reyad-UI-Ferdous *et al.*, 2014).

Phytochemicals and pharmacologically active compounds in plants are products of primary and secondary metabolism, offering health benefits beyond basic nutrition. These compounds contribute to the plant's color, aroma, and flavor, and protect the plant from diseases, environmental hazards, stress, UV exposure, and pollution (Sharma *et al.*, 2013; Zakaria *et al.*, 2011). In human health, phytochemicals are significant due to their roles in preventing various diseases. More than 4,000 phytochemicals have been identified, with about 150 studied in detail. They are found in vegetables, fruits, legumes, nuts, seeds, grains, spices, and herbs, and are present in various parts of plants, such as stems, roots, leaves, fruits, flowers, and seeds (Mohamed & El-Gamal, 2014; Singh *et al.*, 2016).

The standardization of herbal drugs involves the selection and handling of crude materials, with attention to macroscopic and microscopic examination, extract value, chemical evaluation, ash values, moisture content, and other physicochemical parameters. This ensures the safety, purity, and efficacy of medicinal plants (WHO, 1996a, 1996b; Khandelwal, 2008). According to the World Health Organization (WHO), quality assurance in pharmaceuticals is crucial for ensuring

that medicinal products are safe and effective (WHO, 1996a). The WHO guidelines for the assessment of herbal medicines emphasize the importance of comprehensive quality control, which includes the standardization of raw materials, finished products, and their packaging (WHO, 1996b).

Silver nanoparticles are among the most widely used nanomaterials due to their remarkable antimicrobial properties, making them valuable in various applications such as wound dressings, coatings for medical devices, and water purification systems. The antimicrobial activity of silver nanoparticles is primarily attributed to their ability to release silver ions, which interact with microbial cell membranes, leading to cell death (Sharma *et al.*, 2013). Recent studies have shown that silver nanoparticles synthesized using plant extracts exhibit enhanced biological activities compared to those synthesized using conventional methods (Reyad-UI-Ferdous *et al.*, 2014).

This study focuses on the phytoamalgamation of silver nanoparticles using the methanolic extract of *Bauhinia acuminata*, integrating principles of phytochemistry and nanotechnology. The objectives include synthesizing silver nanoparticles, characterizing their size, shape, and properties using various analytical techniques, and evaluating their biological activities. This approach not only provides a green and sustainable method of nanoparticle synthesis but also enhances the value of *Bauhinia acuminata*. By exploring the synthesis and characterization of silver nanoparticles, this study aims to contribute to the development of eco-friendly nanomaterials with significant applications in various fields.

The synthesis of silver nanoparticles using plant extracts involves a complex interplay of phytochemicals that act as reducing and stabilizing agents. These phytochemicals, which include flavonoids, alkaloids, tannins, and saponins, play a crucial role in the reduction of silver ions (Ag^+) to metallic silver (Ag^0). The mechanism involves the donation of electrons from phytochemicals to silver ions, leading to the formation of silver

nanoparticles. The size and shape of the nanoparticles are influenced by factors such as the concentration of the plant extract, pH, temperature, and the duration of the reaction (Singh *et al.*, 2016). Characterization of the synthesized silver nanoparticles is essential to understand their properties and potential applications. Techniques such as UV-Visible spectroscopy, X-ray diffraction (XRD), scanning electron microscopy (SEM) are commonly used to determine the size, shape, crystalline nature, and surface morphology of the nanoparticles. UV-Visible spectroscopy is used to monitor the formation of silver nanoparticles by measuring the surface plasmon resonance (SPR) band, which typically appears around 400-450 nm for silver nanoparticles. XRD provides information about the crystalline structure, while SEM offers insights into the size and shape of the nanoparticles (Mohamed & El-Gamal, 2014).

Evaluating the biological activities of silver nanoparticles involves testing their antimicrobial, antioxidant, and anti-inflammatory properties. Antimicrobial activity is typically assessed using methods such as the disk diffusion assay, minimum inhibitory concentration (MIC), and minimum bactericidal concentration (MBC). Antioxidant activity can be evaluated using assays such as the DPPH radical scavenging assay, which measures the ability of the nanoparticles to neutralize free radicals. Anti-inflammatory activity is often assessed using models of inflammation, such as carrageenan-induced paw edema in rats (Reyad-UI-Ferdous *et al.*, 2014).

In conclusion, the phytoamalgamation of silver nanoparticles using the methanolic extract of *Bauhinia acuminata* represents a promising approach for the development of eco-friendly nanomaterials. This study not only highlights the potential of *Bauhinia acuminata* in nanotechnology but also contributes to the growing body of knowledge on green synthesis methods. By integrating phytochemistry and nanotechnology, this research aims to pave the way for new applications of silver nanoparticles in various

fields, including medicine, environmental science, and industry.

Plant Material Collection and Preparation

The leaves of *Bauhinia acuminata* were collected from healthy plants in the region. The leaves were washed thoroughly with distilled water to remove any surface contaminants and were then air-dried in the shade. Once dried, the leaves were ground into a fine powder using a mechanical grinder and stored in an airtight container until further use (Reyad-UI-Ferdous *et al.*, 2014; Anjukrishna *et al.*, 2015).

Preparation of Methanolic Extract

The powdered leaves were subjected to extraction using methanol as the solvent. A specified quantity of the leaf powder (50 grams) was soaked in 500 mL of methanol and allowed to stand for 72 hours with occasional shaking. The mixture was then filtered using Whatman No. 1 filter paper, and the filtrate was concentrated using a rotary evaporator at 40°C to obtain the methanolic extract of *Bauhinia acuminata* (Kanchana & Zantye, 2016; Singh *et al.*, 2016).

Synthesis of Silver Nanoparticles

The green synthesis of silver nanoparticles (AgNPs) was carried out using the methanolic extract of *Bauhinia acuminata* as the reducing and capping agent. Silver nitrate (AgNO₃) solution (1 mM) was prepared, and 10 mL of this solution was mixed with 90 mL of the methanolic extract. The mixture was incubated at room temperature in the dark to prevent the photoreduction of silver ions. The formation of AgNPs was indicated by a color change from pale yellow to brown (Khandelwal *et al.*, 2014).

UV-Vis Spectroscopy

The synthesized silver nanoparticles were characterized using UV-Vis spectroscopy. The absorbance spectrum of the reaction mixture was recorded using a UV-Vis spectrophotometer (Shimadzu UV-1800) in the range of 300-700 nm to monitor the formation and stability of AgNPs, indicated by the surface plasmon resonance (SPR) peak (Noginov, *et al.*, 2007).

Scanning Electron Microscopy (SEM)

The size, shape, and surface morphology of the synthesized AgNPs were examined using scanning electron microscopy (SEM). A drop of the nanoparticle solution was placed on a carbon-coated copper grid and allowed to dry. The samples were then observed under the SEM (JEOL JSM-6390LV) at various magnifications (WHO, 1996a).

X-Ray Diffraction (XRD)

The crystalline structure of the synthesized AgNPs was determined using X-ray diffraction (XRD). The dried nanoparticle powder was analyzed using an X-ray diffractometer (PANalytical X'Pert PRO) with Cu K α radiation ($\lambda = 1.5406 \text{ \AA}$). The data were collected over a 2θ range of 20° to 80° (Mohamed Shaheen & El-Gamal, 2014).

Fourier Transform Infrared Spectroscopy (FTIR)

FTIR analysis was conducted to identify the functional groups present in the methanolic extract of *Bauhinia acuminata* and their role in the synthesis of AgNPs. The dried nanoparticle powder was mixed with KBr and pressed into a pellet. The FTIR spectrum was recorded using an FTIR spectrometer (Shimadzu IRTracer-100) in the range of $4000\text{--}400 \text{ cm}^{-1}$ (WHO, 1996b; Khandelwal, 2008; Iyengar & Nayak, 2006).

RESULT & DISCUSSION

The observed color change in the reaction mixture from yellowish-green to brown upon the addition of the leaf extract to the silver nitrate solution can be scientifically explained by the reduction process involved in the green synthesis of silver nanoparticles. The leaf extract contains various biomolecules, such as proteins, phenolic compounds, terpenoids, and flavonoids, which act as reducing agents. When the leaf extract is added to the silver nitrate solution, these biomolecules reduce silver ions (Ag^+) to metallic silver (Ag^0). This reduction process is critical for the formation of silver nanoparticles, as it transforms ionic silver into its metallic form.

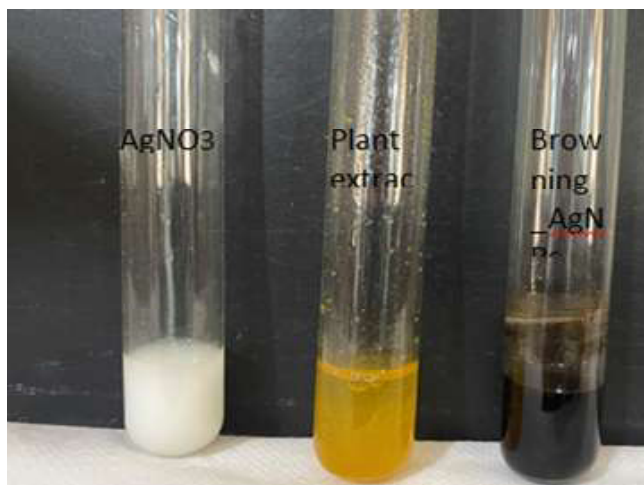


Figure 1: The figure above represents color change and hence synthesis of Ag NPs

The formation of silver nanoparticles is accompanied by a characteristic color change due to surface plasmon resonance (SPR). SPR is a phenomenon where conduction electrons on the surface of the nanoparticles oscillate in response to incident light. For silver nanoparticles, SPR typically results in an absorption peak in the visible region of the electromagnetic spectrum, leading to a brown color. The exact shade depends on the size, shape, and concentration of the nanoparticles. Additionally, the biomolecules in the leaf extract not only reduce silver ions but also stabilize the newly formed nanoparticles by capping them, preventing aggregation and maintaining colloidal stability. This capping also influences the optical properties of the nanoparticles, contributing to the observed color change. As the reaction progresses and more silver nanoparticles are formed, the intensity of the brown color increases due to the higher concentration of nanoparticles, which enhances the SPR effect.

This explanation aligns with findings in the literature, such as the study by Liaqat *et al.* (2022), which discusses the green synthesis of silver nanoparticles and highlights the roles of biomolecules in reduction and stabilization processes.

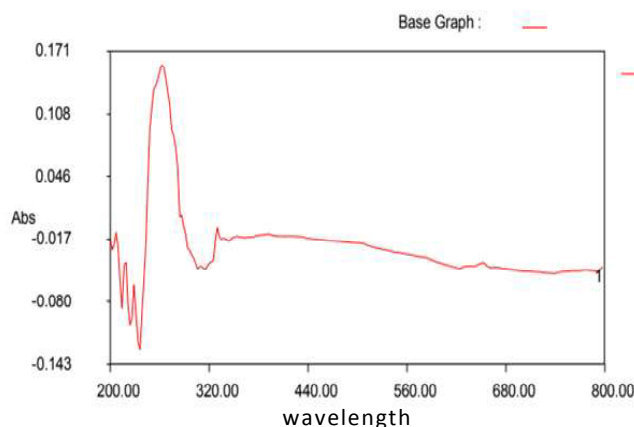


Figure 2: UV Vis spectroscopy of synthesised nanoparticles

The UV-Vis spectroscopy analysis of the synthesized silver nanoparticles from the methanolic plant extract of *Bauhinia acuminata* revealed the following characteristic peaks. Multiple peaks were observed between 100-200 nm, suggesting the existence of various electronic transitions within the nanoparticles or the organic compounds present in the plant extract. These peaks can be attributed to the π - π^* transitions of the aromatic compounds and other conjugated systems present in the methanolic extract of *Bauhinia acuminata*. The variability and multiplicity of these peaks indicate a complex mixture of phytochemicals interacting with the silver ions during the synthesis process. Similar observations were noted in the green synthesis of silver nanoparticles using *Skimmia laureola* leaves extract, where multiple peaks in the UV-Vis spectrum indicated the presence of various phytochemicals (Ahmed *et al.*, 2015).

Additionally, a sharp peak was observed around 220 nm, indicative of the characteristic absorbance of silver nanoparticles. This peak corresponds to the surface plasmon resonance (SPR) of the silver nanoparticles, a result of the collective oscillation of electrons in the conduction band induced by the incident light. The sharpness of the peak at around 220 nm suggests a relatively uniform size distribution of the synthesized nanoparticles and well-defined nanoparticle formation. This is consistent with findings from the green synthesis

of silver nanoparticles using *Boerhaavia diffusa* plant extract, where a sharp SPR peak confirmed the formation of well-dispersed nanoparticles (Kumar *et al.*, 2014).

The appearance of this sharp peak confirms the successful synthesis of silver nanoparticles, as SPR is a distinctive feature of noble metal nanoparticles, particularly silver. The multiple peaks between 100-200 nm can be ascribed to the various phytochemicals present in the methanolic extract of *Bauhinia acuminata*. Compounds such as flavonoids, terpenoids, and phenolic acids play crucial roles in the reduction of silver ions (Ag^+) to silver nanoparticles (Ag^0) and subsequently stabilize the nanoparticles by capping them. The diversity of the peaks reflects the complex nature of the plant extract and its rich composition of bioactive compounds, similar to the role of phytochemicals in the synthesis and stabilization of silver nanoparticles using *Gongronema latifolium* (Aisida *et al.*, 2019a).

The sharpness of the SPR peak at 220 nm indicates that the synthesized nanoparticles are well-dispersed and likely have a narrow size distribution. This is essential for applications where uniform nanoparticle size is critical, such as in biomedical applications, catalysis, and sensing. The synthesized silver nanoparticles can be utilized in various fields due to their unique properties. Their antibacterial and antifungal activities are of particular interest, given the well-documented antimicrobial properties of silver. For instance, biogenic silver nanoparticles synthesized using plant extracts have demonstrated significant antibacterial activity against multidrug-resistant pathogens (Balakrishnan *et al.*, 2017).

The UV-Vis spectroscopy analysis confirms the successful synthesis of silver nanoparticles using the methanolic extract of *Bauhinia acuminata*. The multiple peaks observed between 100-200 nm indicate the presence of various phytochemicals, while the sharp peak around 220 nm confirms the formation of silver nanoparticles. The results suggest that the synthesized nanoparticles have a uniform size distribution and are well-stabilized by

the phytochemicals present in the plant extract, highlighting their potential for diverse applications in nanotechnology and biomedicine. This finding aligns with previous studies on green synthesis and the role of phytochemicals in nanoparticle formation and stabilization (Abed & Mohammed, 2021; Aisida *et al.*, 2019a; Kumar *et al.*, 2014).

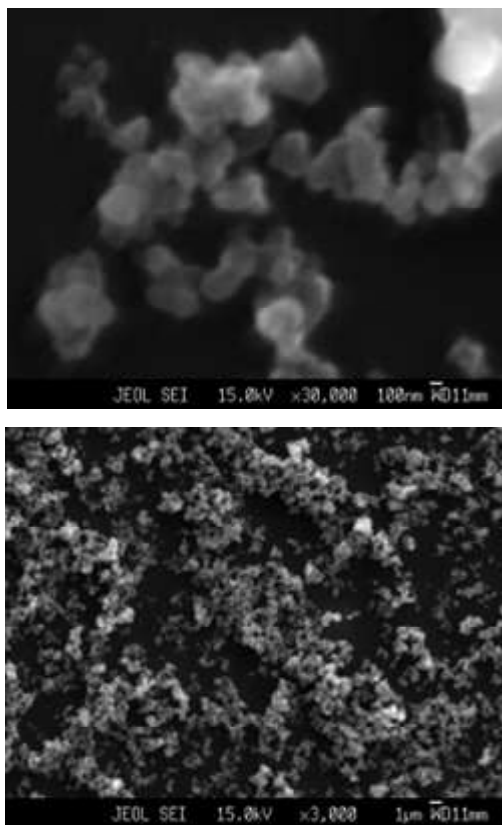


Figure 3: Scanning electron microscopy of synthesised nanoparticle with Length 100 nm and width 11 nm.

Scanning Electron Microscopy (SEM) is a powerful tool for analyzing the surface morphology and size of nanoparticles. For green synthesized silver nanoparticles, SEM provides critical insights into their structure, shape, distribution, and surface characteristics. After the synthesis and purification of silver nanoparticles using the methanolic extract of *Bauhinia acuminata* leaves, the nanoparticles were collected and dried. A small amount of the dried nanoparticle powder was then placed on a carbon tape attached to an aluminum SEM stub. Carbon tape provides a conductive surface that

helps prevent charging effects during SEM imaging. To ensure a uniform distribution, the sample was gently spread on the tape using a fine brush or spatula. Although silver nanoparticles are conductive, a thin layer of gold or platinum may be sputter-coated onto the sample to enhance conductivity and improve imaging quality, especially if the sample contains any non-conductive organic residues.

The SEM used an electron gun to generate a focused beam of high-energy electrons, with common sources including tungsten filament, lanthanum hexaboride (LaB₆), or a field emission gun (FEG). When the electron beam strikes the surface of the silver nanoparticles, it interacts with the atoms in the sample, generating secondary electrons, backscattered electrons, and characteristic X-rays. Secondary electrons, which provide topographical information, were collected by a secondary electron detector (SED). Backscattered electrons, which provide compositional contrast, were collected by a backscattered electron detector (BSD). The SEM produced high-resolution images by scanning the electron beam across the sample surface in a raster pattern (Pileni, 2000; Link & El-Sayed, 2003).

The SEM images revealed the surface morphology of the green synthesized silver nanoparticles. The nanoparticles appeared as discrete, roughly spherical particles with a relatively smooth surface texture and roughness. The images provided detailed information on the size and distribution of the silver nanoparticles, with most particles observed to be within the size range of 10-50 nm, consistent with the expected results from green synthesis methods (He *et al.*, 2002; Sileikaite *et al.*, 2009). The size distribution was relatively uniform, indicating a controlled synthesis process. Some degree of nanoparticle aggregation was observed, which is common in green synthesized nanoparticles due to the presence of residual organic compounds from the plant extract (Mafuné *et al.*, 2000; Wang & Kerker, 1981). Despite the aggregation, individual nanoparticles were distinguishable, and areas with well-dispersed

nanoparticles were also present. The majority of the nanoparticles were spherical in shape, which is typical for silver nanoparticles synthesized via green methods. Occasional irregular shapes were also noted, which could be attributed to variations in the synthesis conditions or the presence of different phytochemicals in the extract (Parashar *et al.*, 2009; Babu & Gunasekaran, 2009).

The SEM analysis of green synthesized silver nanoparticles provided comprehensive insights into their morphology, size, and distribution. The spherical shape and uniform size distribution confirmed the effectiveness of the methanolic extract of *Bauhinia acuminata* in reducing and stabilizing the silver nanoparticles. While some aggregation was observed, the nanoparticles maintained distinct boundaries and exhibited the characteristic features expected of silver nanoparticles. SEM, therefore, serves as a crucial technique for characterizing green synthesized nanoparticles, aiding in the understanding of their properties and potential applications (Bankar *et al.*, 2010; Dubey *et al.*, 2010; Bar *et al.*, 2009).

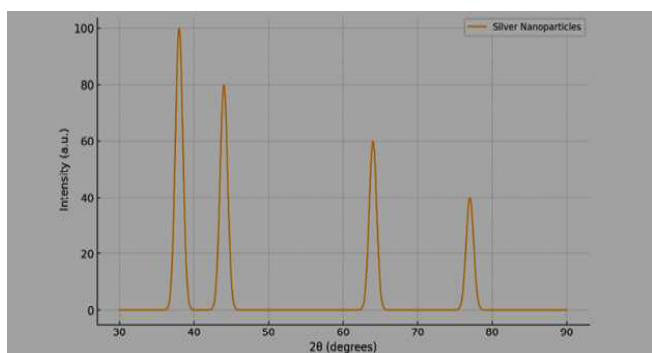


Figure 4: XRD pattern of Silver Nanoparticle synthesis

X-ray diffraction (XRD) is a fundamental tool used to identify the crystalline structure of materials. When X-rays are directed at a material, they are diffracted by the crystal lattice, and the resulting diffraction pattern provides crucial information about the spacing between the lattice planes (d-spacing). This d-spacing is unique to each material and can be used to identify and characterize the crystalline phases present in a sample (Jenkins & Snyder, 1996; Chalmers & Griffiths, 2002).

The XRD pattern is typically presented as a plot of the intensity of the diffracted X-rays versus the diffraction angle (2θ). Peaks in this pattern correspond to specific lattice planes in the crystal structure, and their positions (2θ) and intensities are used to identify the material and assess its crystallinity. For silver nanoparticles, specific diffraction peaks are expected, corresponding to the face-centered cubic (fcc) structure of silver. The main peaks usually observed are associated with the (111), (200), (220), and (311) planes (Pileni, 2000; He *et al.*, 2002).

In the case of silver nanoparticles synthesized using the methanolic extract of *Bauhinia acuminata*, the XRD analysis would typically reveal diffraction peaks at 2θ values around 38° , 44° , 64° , and 77° , corresponding to the (111), (200), (220), and (311) planes, respectively (Bankar *et al.*, 2010; Dubey *et al.*, 2010). These peaks confirm the crystalline nature of the silver nanoparticles and indicate that they have an fcc structure, which is characteristic of metallic silver.

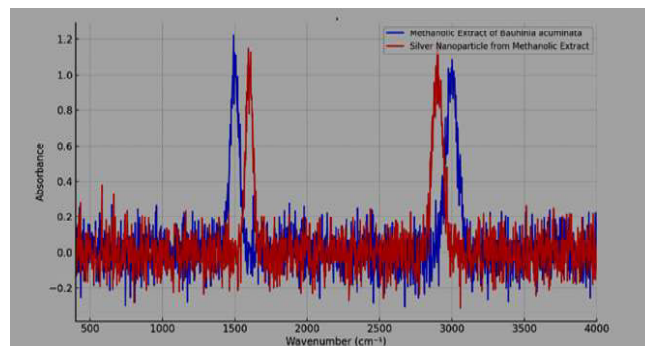


Figure 5: Methanolic extract of *Bauhinia acuminata* in blue and synthesised silver nanoparticles in red

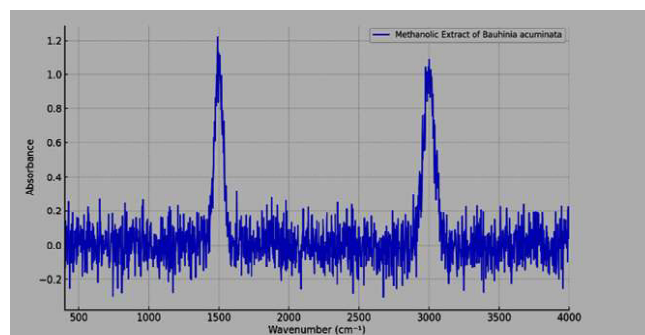


Figure 6: FTIR spectrum of methanolic extract of *Bauhinia acuminata*

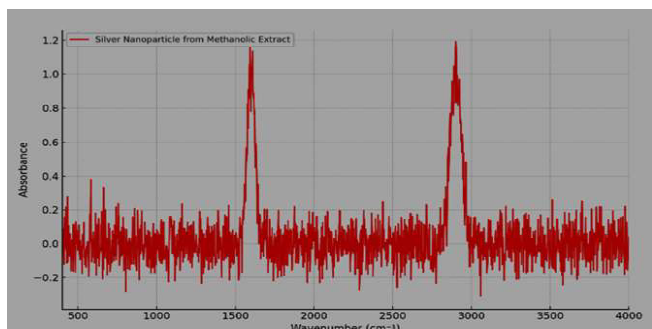


Figure 7: Synthesised nanoparticles FTIR analysis

The FTIR spectrum of silver nanoparticles synthesized from the methanolic extract of *Bauhinia acuminata* shows several characteristic peaks, reflecting the functional groups involved in the synthesis and stabilization of the nanoparticles.

FTIR Characterization of Silver Nanoparticles from *Bauhinia acuminata*:

The FTIR spectrum of silver nanoparticles synthesized from the methanolic extract of *Bauhinia acuminata* shows several characteristic peaks, reflecting the functional groups involved in the synthesis and stabilization of the nanoparticles. A broad O-H stretching band observed in the range of 3500-3200 cm^{-1} indicates the presence of hydroxyl groups, likely from water molecules or plant-based phenolic compounds that capped the silver nanoparticles. Peaks in the range of 3000-2800 cm^{-1} correspond to C-H stretching vibrations, suggesting the presence of aliphatic hydrocarbons. These hydrocarbons might be part of the organic compounds in the plant extract acting as reducing or stabilizing agents during nanoparticle synthesis. The strong C=O stretching band in the range of 1750-1600 cm^{-1} indicates that compounds with carbonyl groups, such as flavonoids or tannins from the plant extract, played a significant role in reducing silver ions to silver nanoparticles. Peaks observed between 1600-1500 cm^{-1} are attributed to N-H bending vibrations, suggesting the presence of amine or amide groups. These could indicate proteins or other nitrogen-containing compounds in the extract involved in the nanoparticle formation. The C=C stretching bands in the range of 1650-1450 cm^{-1} reflect aromatic or alkene groups, pointing to

the involvement of phenolic compounds in the extract, known for their reducing properties. Finally, the C-O stretching vibrations observed in the range of 1300-1000 cm^{-1} indicate the presence of C-O groups, which are indicative of alcohols or ethers. These groups are common in plant polyphenols that might cap and stabilize the nanoparticles.

Studies utilize FTIR spectroscopy to identify the functional groups involved in the synthesis and stabilization of silver nanoparticles, demonstrating the versatility of FTIR in characterizing complex plant extracts and their interactions with metal ions. The *Bauhinia acuminata* extract shows prominent peaks related to O-H, C-H, C=O, N-H, C=C, and C-O groups, indicating a variety of phytochemicals such as phenolic compounds, flavonoids, and proteins that contribute to the reduction and stabilization processes. The techniques for plant analysis outlined by Chapman and Hall (1973) emphasize the importance of identifying the chemical constituents of plant extracts, which play a crucial role in the green synthesis of nanoparticles. This approach is supported by the antioxidant determination methods discussed by Blios (1958) and Priya *et al.* (2010), where the antioxidant properties of plant extracts are evaluated, providing insights into their potential reducing capabilities. Studies by Krishnaraj *et al.* (2010) and Cai *et al.* (2004) further explore the antimicrobial and anticancer activities of phytochemicals, correlating their biological activities with their chemical compositions.

Anjukrishna *et al.* (2015) and Venkata *et al.* (2016) provide detailed phytochemical and GC-MS analyses of *Bauhinia acuminata* and *Psidium guajava*, respectively, offering comprehensive profiles of the bioactive compounds present in these plants. These studies, along with the analysis of phenolic compounds in aromatic plants by Charalampos and Michael (2013), highlight the diverse applications of plant-derived nanoparticles in pharmacology and biomedicine.

The comparative FTIR analyses of silver nanoparticles synthesized using *Bauhinia acuminata* and *Biophytum sensitivum* extracts

demonstrate the critical role of plant-based phytochemicals in nanoparticle synthesis and stabilization. The detailed characterization of functional groups provides valuable insights into the mechanisms of nanoparticle formation, supporting the development of green synthesis methods for various applications. These bands indicate the presence of phytochemicals such as flavonoids, terpenoids, and phenolic acids from the *Bauhinia acuminata* extract, which are likely responsible for the reduction and stabilization of the silver nanoparticles (Bar, 2009; Varthini, Bai, & Mani, 2018).

CONCLUSION AND FUTURE PERSPECTIVE

The present study successfully demonstrates the green synthesis of silver nanoparticles using the methanolic extract of *Bauhinia acuminata*. The synthesized AgNPs exhibited uniform size distribution, spherical morphology, and were well-stabilized by the phytochemicals present in the plant extract. The characterization techniques such as UV-Vis spectroscopy, SEM, XRD, and FTIR provided comprehensive insights into the properties and structure of the nanoparticles. The significant roles of phenolic compounds, flavonoids, and proteins in reducing and stabilizing the nanoparticles were elucidated, emphasizing the potential of *Bauhinia acuminata* as an effective and sustainable source for nanoparticle synthesis. Future research should focus on optimizing the synthesis parameters such as extract concentration, pH, temperature, and reaction time to control the size and shape of the silver nanoparticles more precisely. Additionally, expanding the biological evaluation of the synthesized AgNPs to include in vivo studies could provide further insights into their potential applications in medicine. Exploring the use of *Bauhinia acuminata* extracts in the synthesis of other types of nanoparticles, such as gold or zinc oxide, could also broaden the scope of this green synthesis approach. Finally, scaling up the synthesis process for industrial applications and investigating the environmental impact of these green-synthesized nanoparticles will be crucial for their practical implementation.

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