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Parkia bigalandulosa -Mediated Silver Nanoparticle Synthesis: Comprehensive Analysis through UV, IR, SEM, and TEM Techniques

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Abstracts

The silver nanoparticles, reduced through biological means, exhibited a distinct surface plasmon resonance at 440nm, as evidenced by the UV–visible absorption spectrum analysis. FTIR analysis was employed to identify the compounds responsible for the bio-reduction of silver ions and to elucidate the functional groups present in the leaf extract of P. bigalandulosa. Microscopic studies utilizing Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) further confirmed the spherical shape of the nanoparticles, with an average diameter measuring 15 nm. The comprehensive analysis conducted through diverse spectroscopic and microscopic techniques enhances our understanding of the synthesized silver nanoparticles. This research significantly contributes to the burgeoning field of green synthesis methods, showcasing P. bigalandulosa leaf extract as a promising and sustainable precursor. The detailed characterization is imperative for discerning the potential applications of these silver nanoparticles across various domains, particularly in the realms of biomedical and nanotechnology.

1. Introduction

Silver nanoparticles (AgNPs) possess distinctive optical, thermal, and electrical properties, rendering them versatile for various applications. Over the past decade, AgNPs have found utility in sensors [1–4] , optics [5] , energy [6,7] , and catalysis [8,9] (Zakaria et al., 2020), as well as in the medical and pharmaceutical sectors due to their potent toxicity against microorganisms [10–12]. The capacity of silver nanoparticles to disrupt the plasma membrane of pathogenic microorganisms, thereby inhibiting their activity, has generated considerable interest in their application in healthcare [13]. AgNPs demonstrate non-toxicity towards eukaryotic cells, yet exhibit high toxicity against prokaryotic cells, including gram-positive bacteria, gram-negative bacteria, drug-resistant bacteria, viruses, and fungi [14,15] . Consequently, silver nanoparticles were widely employed as a broad-spectrum antimicrobial compound before the discovery of antibiotics in the early 20th century [16] . Silver nanoparticles (AgNPs) have found application in various biomedical products, including contact lenses, bone cement, surgical masks, nano gels, nano lotions, wound dressing, etc. [17] . Researchers have long been engaged in synthesizing AgNPs to explore their antimicrobial properties. Recent studies by Lara et al. [16] and Swolana et al. [18] demonstrated that AgNPs exhibit antifungal activity against Candida auris, a pathogenic fungus linked to blood serum infections, and antibacterial effects against Staphylococcus epidermidis. The antibacterial impact of AgNPs hinders cell division and DNA replication in bacterial cells by releasing free silver ions from the nanoparticles. These ions interact with the thiol groups of respiratory enzymes and phosphorous-containing bases, preventing cell division and DNA replication [19] . This study focuses on investigating the antibacterial effect of silver nanoparticles synthesized using P. Biglandulosa aqueous leaf extract (PbAgNPs), which acts as both a reducing and capping agent [20]. The antibacterial activity of the synthesized silver nanoparticles depends on the composition, size, shape, surface charge and is also strongly influenced by their method of formation [21] . Researchers have moved to biosynthetic methods for the synthesis of silver nanoparticles to offset some of the disadvantages of using physical and chemical methods, such as the requirement of high temperature, pressure, energy, heavy equipment, and the usage of toxic chemicals [22] . Unlike the conventional methods, the biosynthetic methods do not require a separate stabilizing reagent. The biosynthetic methods are inexpensive, environmental-friendly, don't require high temperature and pressure, and uses non-toxic materials such as bacteria, fungi, yeast, actinomycetes, and plant extracts for stabilization and reduction of nanoparticles [23,24] . It is beneficial to use plant extracts for synthesis rather than microorganisms as we can eliminate the step involving cell culture [25,26]. The reduction of metal ions to nanoparticles by plant extract is called phytomining [25,26] . Biosynthesis of silver nanoparticles using plant extract follows a bottom-up approach. Depending on the various polyphenols and other heterocyclic compounds present in these plant extracts, silver nanoparticles of different morphologies are obtained [27] . Biosynthesized silver nanoparticles have an advantage over conventionally synthesized silver nanoparticles because the phytomolecules involved in the nanoparticle. According to a study, there is a large collection of published studies regarding the biosynthesis of silver nanoparticles using extracts of various parts of the plants such as leaf , bark , flower , fruit , etc. . However, to the best of our knowledge, there have been no reports on the synthesis of silver nanoparticles using P. biglandulosa leaf extract. P. biglandulosa is a perennial deciduous tree belonging to the Fabaceae family. The leaf extract contains steroids, triterpenoids, saponins, tannins, flavonoids, terpenes, phenols, sterols, protein, amino acid contents, cardiac glycosides, and reducing sugars Aygun et al., 2019 . The leaf extract is also known for its antioxidant property. The phytomolecules present in the leaf extract can act as a capping agent for the stabilization of silver nanoparticles and a reducing agent for the reduction of silver ions from $Ag+$ to Ag^0 . Hence, it can be considered as a viable alternative to the physical and chemical methods for the synthesis of silver nanoparticles[28-30].

In this study, the researchers biosynthesized AgNPs by the reduction of Silver nitrate by P. biglandulosa leaf extract. For the comparative study, they chemically synthesized silver nanoparticles (AgNPs) using sodium borohydride as the reducing agent. The characterization of the size and other morphological properties has been conducted. They have performed the anti-bacterial activity studies against Bacillus cereus, a gram-positive bacterium, and also the cell viability studies using human skin fibroblast cells.

2. Materials and methods

2.1. Chemicals

Silver nitrate ($AgNO3$) and sodium borohydride ($NaBH4$) were used for the synthesis of AgNPs. The glasswares used for the experiment were thoroughly cleansed, rinsed in distilled water, and

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dried in a hot air oven. The Petri dishes used for antibacterial studies were autoclaved before the study. The fresh P. biglandulosa leaves were collected from GVISH, amravati and were identified by the Plant taxonomist at the Department of Botany . All the other necessary chemicals were purchased from Sigma-Aldrich. The leaves were washed with purified water and dried in a hot air oven at 50°C overnight. The dried leaves were crushed and ground in a mixer grinder and mixed with sterilized distilled water. This was filtered through a Whatman No.1 filter paper to obtain the leaf extract. AgNPs of 80 mM were synthesized by dissolving 0.470g of silver nitrate in 30 ml of aqueous solution of the above prepared P. biglandulosa leaf extract. The reaction mixture was continuously stirred until a color change was observed from yellowish-brown to greyish-brown. The reaction mixture was irradiated with microwave irradiation for about 120 s and the color of the extract turned to dark brown color . Tyndall effect was observed in the presence of light[31-35].

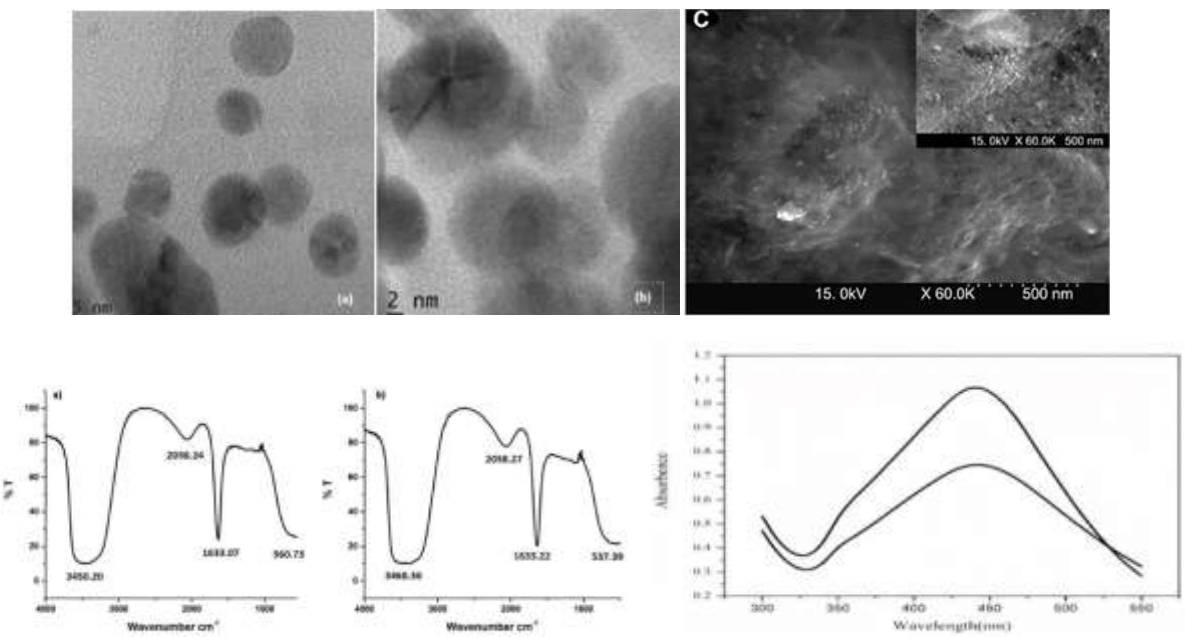

Fig . A,B represent TEM,C represent SEM, D represent FTIR,E represent U.V.

3. Results and discussions

3.1. Formation of the silver nanoparticles

After 30 minutes, signifying the full formation of silver nanoparticles, a noticeable color change occurred. In the absence of the leaf extract, no change in color was observed, indicating the absence of silver nanoparticles. The UV–visible spectrophotometer's absorption spectra provided additional confirmation of silver nanoparticle formation, with the maximum absorbance recorded at 440 nm. The intense absorption of radiation at this wavelength is attributed to the oscillation of free electrons within the synthesized silver nanoparticles. A peak in Fig. 1(c) exhibits lower absorbance due to further sample dilution. FTIR analysis was employed to identify the biomolecules acting as both reducing and capping agents in the reduction of Ag ions. The FTIR spectrum of P. biglandulosa leaf extract revealed distinct absorption peaks at various locations, including 3420 cm^1, 2024 cm^1, 1607 cm^1, and 573 cm^1 (Fig. 2) [38]. The absorption band at 573

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cm1 was attributed to C–Cl stretching of halogen compounds, while 2024 cm1 was associated with alkynyl C–—C stretching, and 1637 cm1 had a specific assignment. The FTIR spectrum revealed specific absorption bands for the PbAgNPs, with peaks at 3436 cm^1, 2027 cm^1, 1622 cm^1, and 529 cm1. These correspond to carbonyl group stretching, alkynyl C–—C stretching, and other relevant functional groups. Notably, the similarity between the FTIR spectra of the PbAgNPs and the leaf extract suggests the presence of residual moieties from the phytomolecules, serving as stabilizing agents. The carbonyl groups in the extract form amino acid residues, leading to protein formation, which binds strongly to the metal, acting as a capping agent and preventing agglomeration [38]. The stability of PbAgNPs for approximately 2 months indicates effective stabilization. The interaction in the hydroxyl group area and the fingerprint region suggests the involvement of flavonoids, alcoholic and phenolic compounds, tannins, terpenoids, and glycosides present in the leaf extract in the reduction of Ag ions [39,40] . SEM image spiral spherical structure.TEM images revealed that the PbAgNPs exhibited a predominantly spherical shape with monodispersed distribution and an average particle size of 15 nm. At low resolution, the nanoparticles were well-separated, displaying uniform interparticle separation (Fig.). The TEM images (Fig. 3a and b) indicated that the surface of the silver nanoparticles was coated with an organic layer. This organic layer, as identified by FTIR analysis, consisted of phytomolecules such as flavonoids, alcoholic and phenolic compounds, tannins, terpenoids, and glycosides. These phytomolecules played a crucial role in the reduction of Ag ions and the stabilization of the nanoparticles' surface. The majority of particles were not in contact with each other but were separated by the organic layer, indicating effective dispersion in the bio-reduced aqueous solution [41]. The selected area electron diffraction pattern confirmed the crystalline nature of the PbAgNPs, with bright circular spots indicating their single-crystalline nature [42]..

4.Conclusion

In this study, silver nanoparticles were biologically synthesized utilizing the leaf extract of P. biglandulosa and comprehensively characterized through UV–Visible spectroscopy,SEM TEM, and IR analyses. The synthesized silver nanoparticles exhibited remarkable stability for approximately 2 months without any agglomeration.SEM, TEM results revealed that the silver nanoparticles predominantly exhibited a spherical shape with an average particle size of 15 nm. Additionally, These findings suggest that the developed biosynthesized silver nanoparticles hold potential for diverse medical and pharmaceutical applications.

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