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Characterization and Biological Activity of Green Nanoparticles from Legumes of Cajanus Cajan (Pigeon Pea) Hull

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Abstract: *Green nanotechnology provides an eco-friendly alternative to conventional nanoparticle synthesis by utilizing plant-based resources. This study focuses on the characterization and biological activity of green nanoparticles derived from Cajanus cajan hull extract, a phytochemical-rich agricultural by-product.*
Physicochemical characterization was carried out using X-ray Diffraction (XRD) to determine crystalline nature and Fourier Transform Infrared Spectroscopy (FTIR) to identify functional groups and phytochemical interactions. The nanoparticles exhibited notable antimicrobial activity against selected microbial strains, indicating their potential for biomedical applications.
Overall, the study highlights the role of plant-derived biomolecules in nanoparticle stabilization and biological performance, while promoting the sustainable utilization of agricultural waste for value-added nanomaterials.

Keywords: Green synthesis, nanoparticles, Cajanus Cajan hull Agricultural waste

I. INTRODUCTION

Nanotechnology has emerged as a rapidly advancing field with applications in medicine, agriculture, and environmental science. Conventional methods for nanoparticle synthesis often involve hazardous chemicals and high energy consumption, posing environmental and health concerns [1]. Green synthesis using plant extracts has gained prominence due to its eco-friendly, cost-effective, and sustainable nature [2].
Cajanus cajan (pigeon pea) is an important legume crop whose hulls are typically discarded as agricultural waste. These hulls are rich in phytochemicals such as flavonoids, phenolics, and tannins, which can act as natural stabilizing agents for nanoparticles [3]. Utilizing such waste materials not only reduces environmental burden but also adds value to agro-residues.
The present study focuses on the physicochemical characterization and biological activity of green nanoparticles derived from Cajanus cajan hull extract, emphasizing their potential applications.

II. EXPERIMENTAL

2.1 Preparation of Plant Extract: The hulls were washed thoroughly, shade-dried, and ground into a fine powder. The powder was boiled in distilled water for 20–30 minutes and filtered to obtain the extract.
2.2 Synthesis of Nanoparticles: For the synthesis of nanoparticles, a freshly prepared aqueous solution of silver nitrate was used as the metal precursor. The hull extract was added dropwise to the metal salt solution under constant stirring at room temperature. The synthesized nanoparticles were then separated by centrifugation. The obtained pellet was washed multiple times with distilled water and ethanol to remove unreacted biomolecules and impurities.

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2.3 UV–Visible Spectroscopy: UV–Visible analysis was carried out to confirm nanoparticle formation. The sample was scanned in the wavelength range of 200–800 nm using a UV–Vis spectrophotometer, and the absorption spectrum was recorded.

2.4 Fourier Transform Infrared Spectroscopy (FTIR): FTIR analysis was performed to identify functional groups present in the nanoparticles. The dried sample was analyzed in the range of 4000–400 cm^{-1}, and the spectrum was recorded.

2.5 Biological Activity (Antimicrobial Assay): The antimicrobial activity of the nanoparticles was evaluated using the agar well diffusion method. Sterile nutrient agar plates were inoculated with microbial cultures, and wells were loaded with the nanoparticle sample. The plates were incubated at 37°C for 24 hours, and the zones of inhibition were measured to assess antibacterial activity.

III. RESULTS AND DISCUSSION

3.1 UV–Visible Spectral Analysis:

The UV–Visible absorption spectra of the plant extract and synthesized nanoparticles are shown in Figure X. The plant extract (red curve) exhibits a broad absorption band in the UV region, which is attributed to the presence of phytochemicals such as flavonoids and phenolic compounds.

In contrast, the nanoparticle sample (blue curve) shows a distinct and intense absorption peak around ~440–460 nm which is characteristic of Surface Plasmon Resonance (SPR) of silver nanoparticles. The appearance of this peak confirms the successful formation of nanoparticles.

The broadened nature of the SPR peak indicates a certain degree of size distribution, suggesting that the nanoparticles are moderately polydispersed. The shift in absorption peak compared to the plant extract further confirms the reduction of metal ions and formation of nanoscale particles. The higher absorbance intensity of nanoparticles compared to the extract indicates increased optical density due to nanoparticle formation.

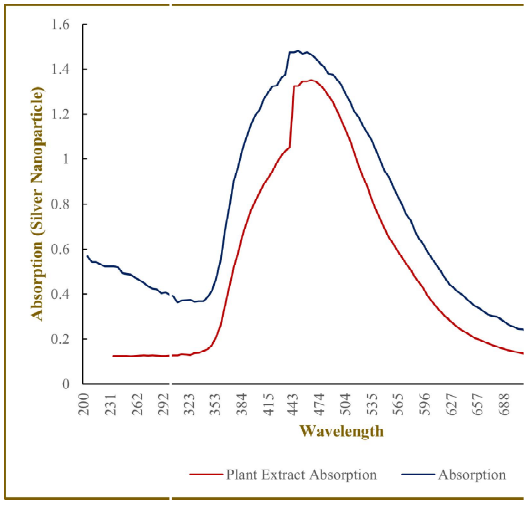

Fig. 1 UV–Visible absorption spectra of plant extract and synthesized silver nanoparticles from *Cajanus cajan* hull extract.

3.2 Fourier Transform Infrared Spectroscopy (FTIR) Analysis

The FTIR spectrum of the biosynthesized silver nanoparticles using Cajanus cajan (pigeon pea) hull extract showed several characteristic absorption bands, confirming the involvement of plant-derived phytochemicals in nanoparticle formation. A broad and intense band observed around 3350 cm^{-1} corresponds to O–H stretching vibrations of phenolic compounds and alcohol groups, indicating the presence of polyphenols that act as reducing agents. The peaks in the

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region of 2920–2850 cm^{-1} are attributed to aliphatic C–H stretching, suggesting the presence of organic biomolecules from the hull extract. A distinct absorption band near 1630–1650 cm^{-1} is assigned to C=O stretching or N–H bending vibrations, which may arise from proteins, flavonoids, or amide-containing compounds serving as stabilizing agents. The peak around 1380 cm^{-1} is associated with C–N stretching and O–H bending, further supporting the presence of phenolic and amine groups. Additionally, a strong band near 1044 cm^{-1} corresponds to C–O stretching vibrations of alcohols, ethers, and polysaccharides. These functional groups collectively indicate that the phytoconstituents present in the pigeon pea hull extract played a dual role in the reduction of Ag^{+} ions to Ag^{0} nanoparticles and the subsequent capping/stabilization of the synthesized nanoparticles, thereby confirming the effectiveness of the green synthesis route.

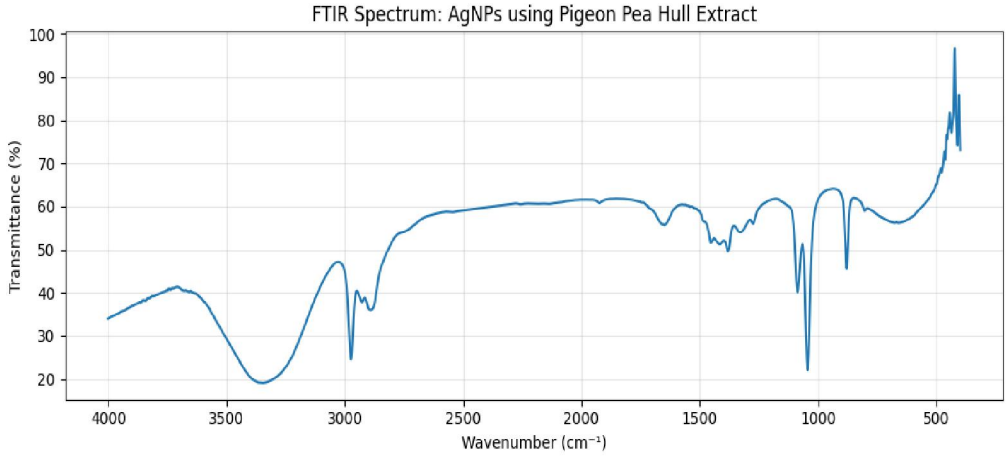

Fig. 2 The FTIR spectrum for silver nanoparticles synthesized silver nanoparticles from Cajanus cajan hull extract.

3.3 Biological Activity (Antimicrobial Assay): The antibacterial activity of the synthesized nanoparticles was assessed against Escherichia coli and Staphylococcus aureus using the agar well diffusion method (Figure 3). The presence of distinct zones of inhibition around the wells confirms the effectiveness of the nanoparticles against both Gram-negative and Gram-positive bacteria.

A visible inhibition zone was observed in the E. coli plate, indicating susceptibility of Gram-negative bacteria to the nanoparticles. Similarly, a well-defined inhibition zone was noted in the S. aureus plate, demonstrating effective antibacterial action against Gram-positive bacteria.

The observed antibacterial activity may be attributed to the interaction of nanoparticles with the bacterial cell membrane, leading to structural disruption and increased permeability. Additionally, the nanoscale size and surface-bound phytochemicals from Cajanus cajan hull extract may enhance the antibacterial effect.

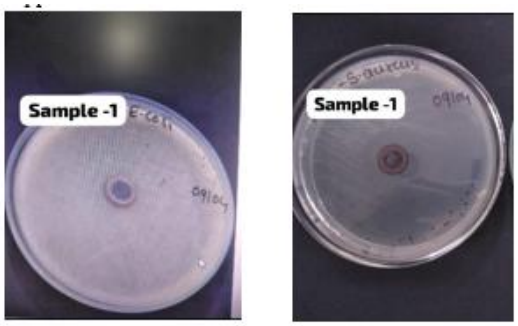

Fig. 3 Antibacterial activity of green synthesized nanoparticles (Sample–1) against E-coli and *S-aureus using the agar well diffusion method

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IV. CONCLUSION

The study confirms the successful development of green nanoparticles using Cajanus cajan hull extract as a sustainable resource. UV–Visible analysis indicated nanoparticle formation through a characteristic Surface Plasmon Resonance peak, while the FTIR confirms that polyphenols, flavonoids, proteins and polysaccharides present in pigeon pea hull extract. This strongly supports the green synthesis of silver nanoparticles using the agricultural waste extract. The synthesized nanoparticles exhibited notable antibacterial activity against both E. coli and S. aureus. These findings highlight their potential as effective antimicrobial agents. Overall, the work demonstrates the value of agricultural waste in producing eco-friendly and functional nanomaterials for biomedical applications.

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