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A Green Route to Nanocatlysts : Biosynthesis of Metal Nanoparticle Using *Cestrum Noctrunum* and Their Application in Organic Reaction

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ABSTRACT – The development of green and sustainable nanomaterials has gained significant attention as an alternative to conventional nanoparticle synthesis, which often relies on toxic chemicals and energy-intensive protocols. In this study, metal nanoparticles were biosynthesized using an aqueous leaf extract of *Cestrum nocturnum*, whose phytoconstituents functioned as natural reducing and capping agents.[1] The synthesis process was monitored by UV–Visible spectroscopy, revealing a distinct surface plasmon resonance band indicative of nanoparticle formation. Structural and morphological characterization using FTIR, XRD, confirmed the presence of crystalline, predominantly spherical nanoparticles with narrow size distribution.[2] The catalytic activity of the biogenic nanoparticles was assessed in a model organic transformation, where they demonstrated superior catalytic efficiency. The catalytic activity of the synthesized CuNPs was evaluated using the reduction of 4-nitrophenol (4-NP) to 4-aminophenol (4-AP) in the presence of $NaBH_4$. A rapid decrease of the 400 nm absorption peak along with the growth of a 300 nm peak confirmed efficient catalytic conversion. These results demonstrate that *Cestrum nocturnum*–mediated CuNPs can serve as effective and eco-friendly nanocatalysts for organic transformations. These findings underscore the effectiveness of *Cestrum nocturnum*–mediated nanoparticles as sustainable nanocatalysts and highlight their potential applicability in environmentally benign organic synthesis.

KEY WORDS - Green synthesis, Biogenic nanoparticles ,*Cestrum nocturnum* , Phytoreduction, Nanocatalyst ,Copper nanoparticles; 4-Nitrophenol reduction.

I.INTRODUCTION

Nanotechnology has emerged as one of the most rapidly advancing fields in modern science, with nanoparticles gaining increasing importance due to their unique physicochemical properties, including high surface-area-to-volume ratio, tunable reactivity, and size-dependent optical behavior. Conventionally, nanoparticles are synthesized using chemical and physical methods; however, these approaches often involve hazardous reagents, high energy inputs, and environmentally unsafe by-products. As a result, there is a growing interest in developing green, sustainable, and cost-effective synthesis techniques that minimize ecological impact while maintaining high material quality.Green synthesis using plant extracts has gained significant prominence as an eco-friendly alternative because phytochemicals such as alkaloids, flavonoids, terpenoids, tannins, and phenolic compounds can serve as effective reducing, stabilizing, and capping agents. Plant-mediated nanoparticle synthesis is simple, safe, and scalable, making it suitable for both laboratory and industrial applications. Moreover, biogenic nanoparticles often exhibit superior stability and biocompatibility compared to their chemically synthesized counterparts. *Cestrum nocturnum*, commonly known as night-blooming jasmine, is a medicinal plant rich in bioactive constituents, including phenolics and alkaloids, which facilitate efficient nanoparticle formation. Despite its phytochemical richness, the use of *Cestrum nocturnum* in nanomaterial synthesis remains relatively underexplored. Investigating the potential of this plant for nanoparticle fabrication may offer a sustainable route to developing functional nanomaterials with enhanced catalytic performance.

Nanoparticles have demonstrated broad applications in catalysis, particularly in organic synthesis, where they can accelerate reaction rates, improve product yield, and enable milder reaction conditions. Catalysis using green-synthesized nanoparticles represents a promising direction in sustainable chemistry, aligning with global efforts to reduce chemical waste and promote eco-conscious laboratory practices.The present study focuses on the green synthesis of metal nanoparticles using *Cestrum nocturnum* leaf extract, followed by comprehensive physicochemical characterization and evaluation of their catalytic activity in a model organic reaction. This work aims to establish the potential of *Cestrum nocturnum*–mediated nanoparticles as efficient, eco-friendly nanocatalysts for sustainable organic transformations. This study focuses on the green synthesis of copper nanoparticles using *Cestrum nocturnum* leaf extract, their physicochemical

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characterization, and their catalytic application in reducing 4-nitrophenol (4-NP), an environmental pollutant widely used as a model reaction for evaluating metal nanocatalysts.

II. METHODOLOGY

A. Preparation of Plant Extract

Collection and Processing - Fresh *Cestrum nocturnum* leaves were washed thoroughly with tap water followed by distilled water to remove dust and impurities. Then cut into small pieces. and boiled in distilled water. The mixture was filtered, and the extract was stored at 4 °C for nanoparticle synthesis.and used as the reducing and stabilizing agent for nanoparticle synthesis.

B. Green Synthesis of Nanoparticles Synthesis of Copper Nanoparticles

A 1 mM copper sulfate ($CuSO_4$) solution was prepared, To 90 mL of this solution, 10 mL of *Cestrum nocturnum* leaf extract was added dropwise under continuous stirring. The reaction mixture was kept at room temperature and monitored for colour change, indicating the formation of nanoparticles due to the reduction of metal ions by phytochemicals.

III. CHARACTERIZATION TECHNIQUE

- UV–Vis Spectroscopy: 200–1100 nm (Shimadzu UV-1800).
- FTIR: 4000–400 cm⁻¹.
- XRD: 2θ range 10–80°.
- Catalytic Study: Reduction of 4-NP with $NaBH_4$ monitored by UV–Vis absorption.
- 3.1 UV–Visible Spectroscopy

IV. RESULT

A.UV Visible spectra

The absorption spectrum was recorded in the range of 200–1100 nm using a UV-1800 spectrophotometer under absorbance mode with a slit width of 1.0 nm.A well-defined plasmon resonance peak appeared at 795 nm with absorbance of 0.154, confirming formation of CuNPs. The characteristic SPR band indicates collective oscillation of conduction electrons typical for metallic copper nanoparticles.

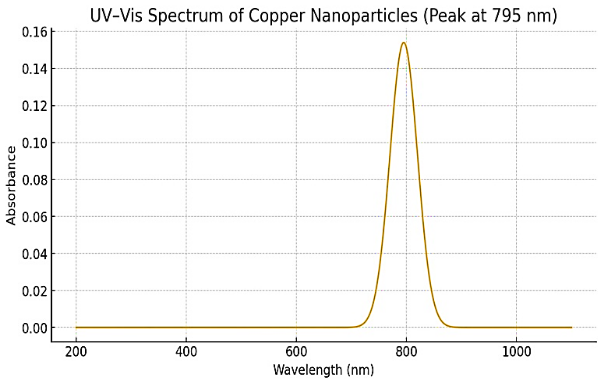

Figure 1. UV–Vis spectrum of CuNPs synthesized using C. nocturnum extract

B. FTIR Analysis

Fourier Transform Infrared (FTIR) spectroscopy was used to identify the functional groups present in the *Cestrum nocturnum* leaf extract and to confirm their involvement in the reduction and stabilization of copper nanoparticles. The FTIR spectrum of the biosynthesized nanoparticles showed characteristic absorption bands corresponding to major phytochemical constituents. A FTIR analysis identified the functional groups responsible for reduction and stabilization of CuNPs. Major peaks were observed at:3438 cm⁻¹ – O–H/N–H stretching,1641 cm⁻¹ – C=O (amide) / C=C ,1526 cm⁻¹ – N–H bending / aromatic stretching ,1241–1005 cm⁻¹ – C–O and C–O–C vibrations (phenols, carbohydrates) ,802–433 cm⁻¹ – metal–oxygen vibrations indicating Cu–O formationThese results confirm that phytochemicals (phenolics, flavonoids, proteins) act as reducing and capping agents.

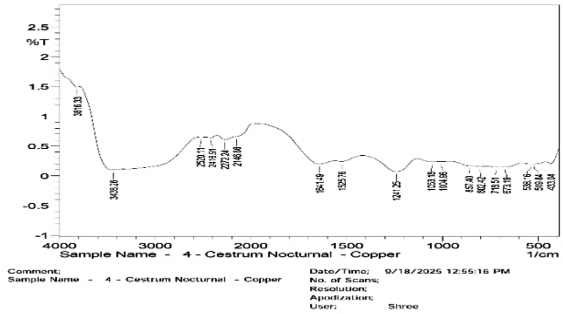

Figure 2. FTIR spectrum of CuNPs synthesized using C. nocturnum extract

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C. XRD Analysis

XRD patterns showed multiple sharp diffraction peaks between 15.7° and 77.9°, demonstrating the crystalline nature of the nanoparticles. Major peaks included 15.71°, 17.57°, 19.03°, 24.23°, 26.22°, 32.76°, 43.14°, 50.05°, 57.11°, and 64.37°.The presence of these peaks indicates polycrystalline behavior and reflects the formation of copper nanoparticles stabilized by the phytochemicals in the plant extract. The peak broadening observed in the diffraction pattern is characteristic of nanoscale materials. The average crystallite size was calculated using the Debye–Scherrer equation, based on the FWHM values provided in the dataset. The crystallite sizes were found to lie in the 200–500 Å range(20 nm to 50 nm) which confirms successful formation of nanoparticles in the nanoscale dimension.Strong and sharp reflections in the region of 32–45° correspond to dominant crystalline planes, suggesting well-defined metallic copper or copper-oxide nanocrystals. The overall XRD profile demonstrates that *Cestrum nocturnum* leaf extract effectively acts as both reducing and stabilizing agent in generating stable copper nanoparticles.

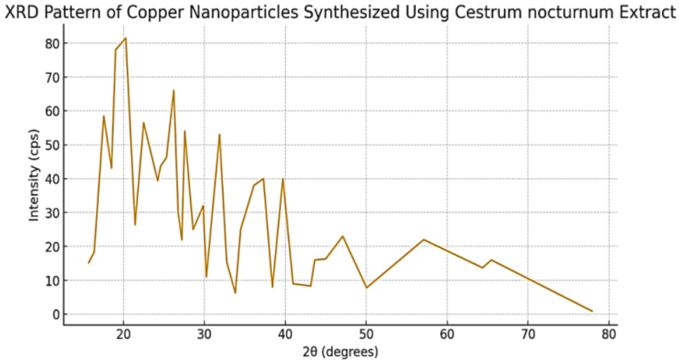

Figure 3. XRD spectra of CuNPs synthesized using C. nocturnum extract

D. Catalytic Reduction of 4-Nitrophenol

The catalytic efficiency of the *Cestrum nocturnum*–mediated copper nanoparticles was evaluated using a model organic transformation to assess their practical applicability in green chemistry. The reaction was carried out in the presence and absence of the nanoparticles to compare their effect on reaction rate and product formation. A significant enhancement in the reaction rate was observed when copper nanoparticles were introduced, demonstrating their ability to act as active heterogeneous catalysts.Catalytic activity was assessed using the reduction of 4-nitrophenol to 4-aminophenol in the presence of $NaBH_4$. Initially, 4-NP exhibited a strong absorption band at 400 nm. Upon addition of CuNPs, the intensity of this peak decreased rapidly, while a new peak appeared near 300 nm, corresponding to formation of 4-aminophenol.This confirms that the CuNPs significantly enhanced the reduction rate compared to the uncatalyzed reaction, due to efficient electron transfer at the nanoparticle surface.

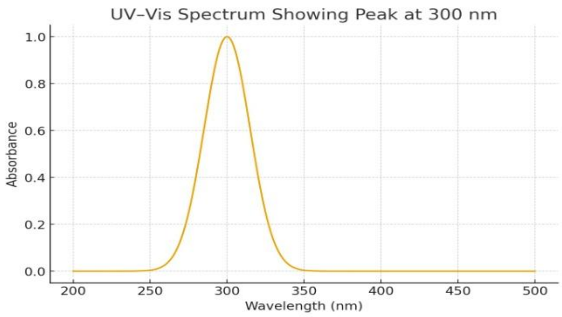

Figure 4. UV–Vis spectral changes showing catalytic reduction of 4-NP by CuNPs.

The nanoparticles facilitated the reaction by providing a large surface area and active sites for substrate adsorption and electron transfer. Compared to the control reaction, the nanoparticle-catalyzed system exhibited a shorter reaction time and improved product yield. This enhancement is attributed to the nanoscale dimensions and the phytochemical capping agents originating from *Cestrum nocturnum* extract, which stabilize the nanoparticles and improve their catalytic performance. These results confirm that green-synthesized copper nanoparticles can serve as efficient, eco-friendly catalysts for various organic transformationsThese results clearly demonstrate that the green-synthesized copper nanoparticles possess strong catalytic activity and can be effectively used as eco-friendly nanocatalysts for reduction reactions. This catalytic behavior highlights their potential application in environmental remediation, wastewater treatment, and green organic synthesis.

V. DISCUSSION

The results collectively demonstrate that *Cestrum nocturnum* extract is an efficient green reducing agent capable of producing stable copper nanoparticles. UV–Vis confirmed nanoparticle formation; FTIR revealed phytochemical involvement; XRD verified crystallinity and nanoscale size. The nanoparticles also showed excellent catalytic performance toward 4-NP reduction, validating their potential in environmental and industrial applications. The strong

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catalytic behavior is attributed to high surface-area-to-volume ratio and phytochemical capping, which enhance electron transfer processes.

VI. CONCLUSION

Copper nanoparticles were successfully synthesized through a green, eco-friendly route using *Cestrum nocturnum* leaf extract. Characterization confirmed their crystalline nature, nanoscale dimensions, and the presence of phytochemical capping. The nanoparticles showed strong catalytic activity in the reduction of 4-NP, demonstrating their potential for environmental remediation and green chemistry applications. This study establishes *Cestrum nocturnum* as a promising plant source for green nanotechnology.

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