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A Comparative Study of Green Synthesis and Characterization of CdS using Curry Leaves (*Murraya Koenigii*) Extract methylation reaction

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Abstract:

Nanotechnology involves the design and manipulation of materials at the nanoscale (1–100 nm), where unique physicochemical properties such as enhanced surface area, optical behavior, and reactivity emerge compared to bulk materials. Conventional methods for nanoparticle synthesis, including physical and chemical approaches, often involve hazardous reagents and high energy consumption, raising environmental concerns. As a result, green synthesis has gained significant attention as an eco-friendly and sustainable alternative, utilizing biological resources like plant extracts as reducing, stabilizing, and capping agents. Among various plant-based approaches, *Murraya koenigii* (curry leaves) has been widely explored due to its rich phytochemical composition, including alkaloids, flavonoids, and phenolic compounds. These bioactive constituents facilitate the efficient synthesis and stabilization of nanoparticles. Additionally, the year-round availability and medicinal significance of *Murraya koenigii* make it a reliable and sustainable choice for green synthesis. Recent studies have demonstrated the successful biosynthesis of cadmium sulfide (CdS) nanoparticles using *Murraya koenigii* leaf extract, showing rapid formation and effective stabilization in solution. The synthesized nanoparticles are typically characterized using techniques such as X-ray diffraction (XRD) for crystallinity, Fourier transform infrared spectroscopy (FTIR) for functional group analysis, and UV-visible spectroscopy for optical properties and band gap evaluation. Furthermore, green-synthesized CdS nanoparticles exhibit notable antibacterial activity against various pathogens, indicating their potential in biomedical applications. Their eco-friendly nature, cost-effectiveness, and scalability also make them suitable for environmental applications, including domestic wastewater treatment. Overall, plant-mediated synthesis using *Murraya koenigii* offers a promising, sustainable approach for producing functional nanomaterials.

Keywords: CdS Nanoparticles, Phytochemicals, eco-friendly, Biogenic, antibacterial activity, sustainable.

Introduction

Nanoparticles have attracted great interest due to their unique physical and chemical properties, which are different from those of either the bulk material or single atoms [1]. Nanoparticles have found applications across scientific and industrial domains due to their unique physicochemical properties, such as high surface area, quantum size effects, and tunable surface functionality. In environmental science, they are used for the removal of heavy metals, dyes, and toxic contaminants from water and soil. In biomedical and pharmaceutical sectors, they are used as agents for drug delivery, imaging, and diagnostics, for targeted and controlled therapeutic effects. The electronics and optoelectronics industries utilize nanoparticles in the fabrication of sensors, solar cells, LEDs, and nano-transistors due to their excellent electrical and optical properties. In catalysis, they act as efficient catalysts or catalyst supports, to alter reaction rates and selectivity [4]. CdS NPs belong to the group of chalcogenides; a II-IV group Semiconductor NPs which are promising because of their narrow band gap, excellent photo response Under visible light, and ability to breakdown Organic pollutants like synthetic dyes [2].

Among various semiconducting materials, cadmium sulphide (CdS) is widely studied due to its favorable semiconductor properties, optoelectronic properties, and structural stability [4]. CdS nanoparticles also have high Photosensitivity that makes them suitable for optoelectronic devices and a number of biological applications [7]. CdS nanoparticles have size-dependent properties, and their synthesis method determines their shape, size and surface charge [4]. Traditional synthesis methods such as solvothermal or hydrothermal processes, thermal decomposition of precursors, and chemical bath deposition (CBD) often involve hazardous chemicals and energy intensive processes, raising concerns about environmental and biological safety [6]. As a sustainable alternative, green synthesis employs biological resources such as plant extracts, which act as both reducing and stabilizing agents in nanoparticle formation. This research aims to investigate the green synthesis of CdS nanoparticles using *Murraya koenigii* (curry leaves) as a Sustainable reducing and stabilizing agent.

The study employs a sol-gel method to produce environmentally friendly Nanoparticles, which are then characterized for their size, morphology, and composition. Advantages of Using Natural Materials *Murraya koenigii*, commonly known as curry leaves, has been identified as a suitable candidate for the green synthesis of nanoparticles. The leaves contain various phytochemicals, including flavonoids, alkaloids, and phenolic compounds, which possess reducing and stabilizing properties. These compounds facilitate the reduction of metal ions to form nanoparticles while simultaneously stabilizing them in solution [3]. Curry leaf is found to be effective as antioxidant, antidiabetic, antibacterial, antihypertensive, and also in the treatment of bronchial respiratory difficulties. In view of its medicinal importance and lack of literature reports on the synthesis of CdS nanoparticles using *M. Koenigii* leaf extract [7]. The benefit of using Curry leaves for nanoparticle synthesis include its abundance i.e present in all seasons, low cost, and biocompatibility. Additionally, the use of plant-based materials minimizes the risk of toxic byproducts associated with chemical synthesis methods. The comprehensive characterization of the biosynthesized CdS nanoparticles confirms their physicochemical suitability for Advanced material applications. The nanoscale crystallite size 5.073 nm and phase purity confirmed by XRD make the material Appropriate for quantum confinement-based optical and electronic applications, such as photodetectors, thin-film photovoltaics, and Optoelectronic devices. The presence of surface hydroxyl and Cd-S vibrational groups observed in FTIR suggests surface Functionalization potential, which is essential for heterogeneous catalysis and sensor interfaces [4]. Studies have shown that nanoparticles synthesized using plant extracts exhibit enhanced biocompatibility and lower toxicity, making them suitable for various applications, including biomedical and environmental fields.

Literature Review

Plenty of rese have managed to make CdS Nanoparticles with plant extracts. for example, **K. R. Kanude & Preeti Jain (2017)** demonstrated the successful green synthesis of CdS nanoparticles using plant extracts, highlighting the potential of natural materials in nanoparticle production. The use of plant extracts not only provides a source of reducing agents but also stabilizes the nanoparticles, preventing agglomeration[7].

Dabhane and his team (2021) examined the eco-friendly methods for synthesizing Cadmium Sulfide (CdS) nanoparticles using plant extracts and microbes and Categorized various biogenic protocols and details the resulting nanoparticle properties, such as size and morphology also emphasized their diverse applications in photocatalysis, sensing, and biomedicine, promoting sustainable alternatives to toxic chemical synthesis[12].

Further, **Reem Younis and her colleagues (2024)** demonstrated that CdS nanoparticles could significantly Reduce the concentration of organic pollutants in wastewater through photocatalytic degradation . They have done the analysis of domestic wastewater before and after the addition of cadmium sulphide nanoparticles (CdS NPs) that Revealed significant changes in key parameters, including Total Organic Carbon (TOC), Total Carbon (TC), Inorganic Carbon (IC), and Dissolved Oxygen (DO)[3].

NITHYA SRI R & JEYANTHI J (2025) Synthesized the CdS Nanoparticles and performed the characterization such that the XRD analysis confirmed the crystalline nature of CdS with an average crystallite size of 5.073 nm, indicating successful nanostructure formation. FTIR spectra showed the presence of -OH and Cd-S bond vibrations, confirming the involvement of plant phytochemicals in capping and stabilizing the nanoparticles. EDS (EDAX) analysis revealed that Cd and S were the predominant elements, with only minor traces of C and O, validating the high purity and successful incorporation of curry leaf extract as a biogenic agent[4].

Research Methodology

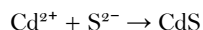
This review looks at research on making CdS nanoparticles using *Murraya koenigii* (curry leaf) extract.

The process starts off simple:

Preparation of Curry leaves Extract: freshly-picked curry leaves are washed well, then air dried under sunlight and then crushed to form a uniform and diluted with distilled water to make the plant extract. This extract is packed with bioactive compounds that help reduce cadmium ions.

Synthesization of CdS Nanoparticles: Next, you prepare precursor solution that is Cadmium Nitrate $\text{Cd}(\text{NO}_3)_2$ and sodium sulfide Na_2S then you have to mix an aqueous solution of cadmium nitrate with the plant extract, keeping everything stirred. Then, sodium sulfide gets added slowly, drop by drop. When the reaction kicks in, you'll see the solution turn yellow—that's the signal that CdS nanoparticles are forming.

Here's the main reaction:



Phytochemicals in the curry leaves, especially flavonoids and phenolic compounds, step in as both reducing and stabilizing agents. They keep the nanoparticles from clumping together.

The outcome depends a lot on details like pH, temperature, concentrations, and how long you let the reaction run. After the nanoparticles form, methods like centrifugation, washing, and drying help clean and purify them.

To check the results, researchers use tools like UV-Visible spectroscopy, XRD, SEM, and FTIR. These techniques confirm the nanoparticles are there and help analyze their structure and properties.

Expected outcomes

This study aims to show that you can successfully make CdS nanoparticles using *Murraya koenigii* leaf extract—a method that's both eco-friendly and sustainable. The phytochemicals in these leaves not only help reduce cadmium ions but also keep the nanoparticles stable. When we check the nanoparticles using standard techniques, we plan to see clear evidence of crystalline CdS with strong optical features. These particles should stay stable, have a uniform look, and mostly fall within the nanoscale size range. We also expect these nanoparticles to have real-world uses. Thanks to their surface properties and reactivity, they should work well in photocatalysis,

optoelectronics, fight off bacteria, and help clean wastewater. All in all, this work supports green chemistry and offers a more affordable, environmentally friendly way to make useful nanoparticles.

Conclusion

Wrapping it up, using *Murraya koenigii* (curry leaf) extract to make CdS nanoparticles is a smart, eco-friendly, and affordable way to go. The natural chemicals in the curry leaves do the heavy lifting—they help reduce and stabilize the nanoparticles, so there's no need for any nasty, toxic chemicals. Tests show these nanoparticles come out just right, with the structural and optical properties you want. Green synthesis doesn't just work well—it's also easier on the environment, cuts costs, and avoids the toxicity issues you get with standard methods. These CdS nanoparticles could really make a difference, especially in cleaning up wastewater and in photocatalysis for environmental and medical uses. All in all, sustainable synthesis really matters, and there's a lot of exciting work ahead for green nanotechnology.

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