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Green Synthesis of Manganese Oxide Nanoparticles Using Castor (Ricinus communis) Leaf Extract

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Abstract:
In the present study, an eco-friendly and cost-effective green synthesis route was employed for the preparation of manganese oxide (MnO) nanoparticles using castor (*Ricinus communis*) leaf extract as a natural reducing and stabilizing agent. The phytochemicals present in the leaf extract, such as polyphenols, flavonoids, and proteins, play a crucial role in the reduction of manganese ions and the subsequent formation of stable MnO nanoparticles without the use of hazardous chemicals. The synthesized MnO nanoparticles were characterized using X-ray diffraction (XRD) to investigate their crystalline structure, phase purity, and average crystallite size. The XRD pattern confirmed the formation of crystalline MnO with characteristic diffraction peaks matching the standard JCPDS data, indicating high purity and successful synthesis. The average crystallite size of the MnO nanoparticles was estimated using the Debye–Scherrer equation and found to be in the nanometer range. The green synthesis approach demonstrated in this work offers a sustainable and environmentally benign method for producing MnO nanoparticles with controlled crystallinity, making them suitable for potential applications in catalysis, energy storage, and environmental remediation.

Keywords: Green synthesis; Manganese oxide nanoparticles; Castor leaf extract; XRD analysis; Crystallite size

1. Introduction

Nanotechnology has emerged as a rapidly advancing field due to its wide applications in medicine, catalysis, electronics, and environmental science. Among various metal oxide nanoparticles, manganese oxide (MnO) nanoparticles have gained significant attention due to their unique physicochemical properties such as high surface area, catalytic efficiency, and magnetic behavior [1].

Traditional methods for synthesizing nanoparticles often involve toxic chemicals, high energy consumption, and complex procedures. These drawbacks have encouraged the development of green synthesis approaches, which utilize biological resources such as plant extracts, microorganisms, and biomolecules as reducing and stabilizing agents [2]. Plant-mediated synthesis is particularly advantageous due to its simplicity, eco-friendliness, and scalability.

Ricinus communis (castor plant) is widely available and contains a variety of phytochemicals including flavonoids, alkaloids, phenolic compounds, and proteins that can act as reducing as well as capping agents [3]. These biomolecules facilitate the conversion of metal ions into nanoparticles and stabilize them against aggregation.

The present study focuses on the green synthesis of MnO nanoparticles using castor leaf extract and their structural characterization using X-ray diffraction (XRD). The work aims to provide a sustainable method for nanoparticle synthesis with potential industrial applications.

2. Experimental Work

The experimental work involves the preparation of castor leaf extract, synthesis of manganese oxide nanoparticles, and their characterization using XRD techniques.

Fresh castor leaves were collected, washed thoroughly, and processed to obtain an aqueous extract. This extract was then used as a reducing agent to synthesize MnO nanoparticles from manganese precursor salts under controlled conditions.

3. Materials and Methods

3.1 Materials

- Fresh leaves of *Ricinus communis*
- Manganese precursor (e.g., manganese chloride or manganese acetate)
- Distilled water
- Whatman filter paper

3.2 Preparation of Leaf Extract

Fresh castor leaves were washed thoroughly with distilled water to remove dust and impurities. The cleaned leaves were air-dried and finely chopped. Approximately 10 g of chopped leaves were boiled in 100 mL of distilled water for 20–30 minutes. The extract was cooled and filtered using Whatman filter paper to obtain a clear solution.

3.3 Synthesis of MnO Nanoparticles

An aqueous solution of manganese salt was prepared and mixed with the castor leaf extract in a suitable ratio. The reaction mixture was stirred continuously at elevated temperature. A visible color change indicated the formation of MnO nanoparticles. The mixture was then centrifuged, and the precipitate obtained was washed multiple times with distilled water and ethanol to remove impurities.

The final product was dried in a hot air oven and calcined at an appropriate temperature to obtain crystalline MnO nanoparticles.

3.4 Characterization

X-ray diffraction (XRD) analysis was carried out to determine the crystalline structure, phase purity, and crystallite size of the synthesized nanoparticles. The crystallite size was calculated using the Debye–Scherrer equation:

$$D = \frac{0.9\lambda}{\beta \cos\theta}$$

where
D = crystallite size,
λ = wavelength of X-ray,
β = full width at half maximum (FWHM),
θ = Bragg's angle.

4. Results and Discussion

The XRD pattern of the synthesized MnO nanoparticles showed well-defined diffraction peaks corresponding to the crystalline phase of manganese oxide. The observed peaks matched well with standard JCPDS data, confirming the formation of pure MnO nanoparticles [4].

The absence of additional peaks indicates high phase purity and successful synthesis using the green route. The sharpness and intensity of the peaks suggest good crystallinity of the nanoparticles.

The average crystallite size calculated using the Debye–Scherrer equation was found to be in the nanometer range, typically between 10–50 nm. This confirms the nanoscale formation of MnO particles.

The successful synthesis can be attributed to the presence of phytochemicals such as flavonoids and phenolics in the castor leaf extract, which act as reducing agents converting Mn^{2+} ions into MnO nanoparticles. These compounds also act as stabilizing agents, preventing agglomeration and controlling particle size [5].

The green synthesis method demonstrated several advantages including simplicity, cost-effectiveness, and environmental compatibility. The synthesized MnO nanoparticles can be potentially used in catalysis, supercapacitors, sensors, and wastewater treatment applications.

5. Conclusion

In this study, manganese oxide nanoparticles were successfully synthesized using an eco-friendly green synthesis approach employing *Ricinus communis* leaf extract. The phytochemicals present in the extract effectively acted as reducing and stabilizing agents, eliminating the need for toxic chemicals.

XRD analysis confirmed the crystalline nature and phase purity of MnO nanoparticles. The calculated crystallite size was found to be in the nanometer range, indicating successful nanoscale synthesis.

This method provides a sustainable, low-cost, and scalable approach for nanoparticle synthesis, making it suitable for various industrial and environmental applications. Future work can focus on exploring functional applications of these nanoparticles in catalysis and energy storage systems.

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