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

Bhoomika Bind[1], Priyal Kangane[2], Bhushan Langi[2], Sandesh Jaybhaye[3]
[1]Department of Biotechnology, B. K. Birla College (Empowered Autonomous Status), Kalyan,
[2]Department of Chemistry, Dnyansadhana College, Thane
[3]Department of Chemistry, B. K. Birla College (Empowered Autonomous Status), Kalyan,

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, including high surface area, catalytic efficiency, and magnetic behaviour [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

MnO NPs Obtained using castor leaves by the green method were analysed by using FT-IR and XRD

4. Results and Discussion

Figure 1 the X-ray diffraction pattern of the synthesized MnO nanoparticles shows well-defined diffraction peaks, confirming the crystalline nature of the material. The intensity vs. 2θ pattern (10°–90°) exhibits several sharp peaks, indicating good crystallinity of the nanoparticles [4]. The main diffraction peaks are observed approximately at 2θ ≈ 18° , 29–30° ,32–36° (most intense peaks), 38° , 50–52° , 58–60° , 64–66°. These peaks correspond to the characteristic planes such as: (111), (200), (220), (311), (222), respectively.

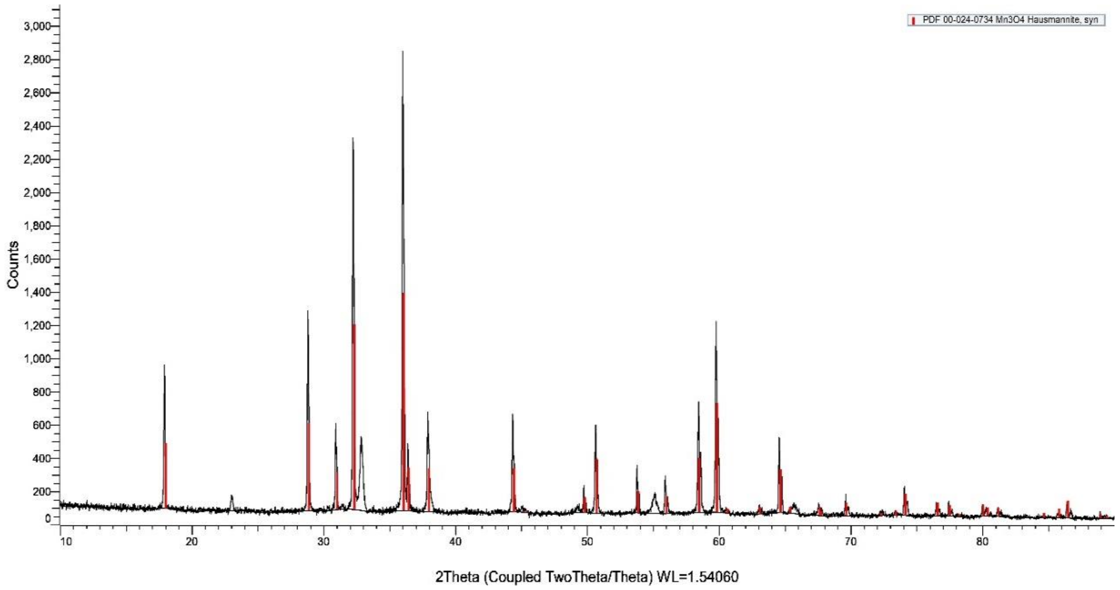

Figure 1 XRD Image of MnONPs obtained using Castor leaves

The peak positions match well with the face-centred cubic (FCC) structure of MnO, consistent with standard JCPDS data (e.g., JCPDS card no. 07-0230). This confirms the successful formation of manganese(II) oxide nanoparticles. The presence of sharp and intense peaks indicates high crystallinity. No significant extra peaks are observed, suggesting phase purity with minimal impurities. Minor background noise may arise due to organic residues from the castor (Ricinus communis) leaf extract, acting as reducing and stabilizing agents.

The peaks show slight broadening, which indicates nanocrystalline size. This broadening is due to small particle size and lattice strain introduced during green synthesis. The crystallite size can be calculated using the Debye–Scherrer equation:

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

Where:

- D= crystallite size
- $\lambda = 1.5406$ Å(Cu Kα radiation)
- β= FWHM of the peak
- θ= Bragg angle

Typically, MnO nanoparticles synthesized via green methods fall in the range of 10–50 nm.

Figure 2 the FT-IR spectrum of manganese oxide nanoparticles (MnONPs) synthesized via *Ricinus communis* (castor) leaf extract reveals important information about the functional groups responsible for reduction, stabilization, and capping of the nanoparticles.

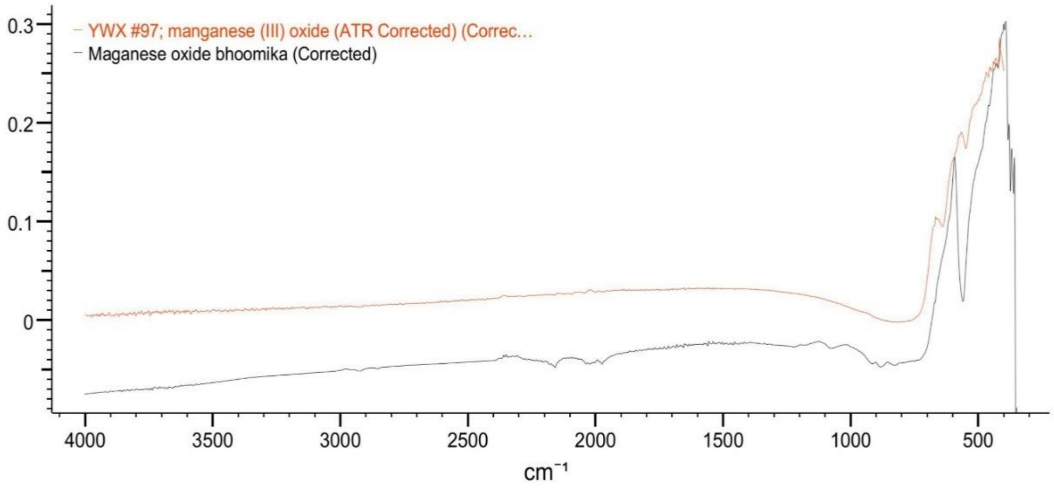

Figure 2 FT-IR Spectrum of MnONPs obtained using Castor leaves

Broad band around 3200–3500 cm^{-1}, a broad absorption band observed in this region corresponds to O–H stretching vibrations of hydroxyl groups present in alcohols and phenolic compounds. These originate from phytochemicals such as flavonoids and polyphenols in the castor leaf extract, indicating their role in reducing Mn ions and stabilizing the nanoparticles.

Weak peaks near 2900 cm^{-1}, these peaks are attributed to C–H stretching vibrations of aliphatic hydrocarbons ($–CH_2$ and $–CH_3$ groups), suggesting the presence of organic biomolecules acting as capping agents.

Peaks around 1600–1650 cm^{-1}, this region corresponds to C=O stretching (amide I) or C=C stretching vibrations, indicating the presence of proteins or polyphenolic compounds. These biomolecules may bind to the nanoparticle surface, enhancing stability.

Bands near 1400–1450 cm^{-1}, these peaks are assigned to C–N stretching or O–H bending vibrations, further confirming the presence of plant-derived organic compounds involved in nanoparticle formation.

Peaks in the range 1000–1100 cm^{-1}, hese are due to C–O stretching vibrations of alcohols, ethers, or esters, indicating residual phytochemicals attached to the nanoparticle surface.

Strong absorption below 600 cm^{-1} (around 500–600 cm^{-1}, A prominent peak in this region is characteristic of Mn–O stretching vibrations, confirming the formation of manganese oxide nanoparticles. This is the most important evidence for MnO phase formation.

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.

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The XRD analysis confirms that the synthesized material is pure, crystalline MnO nanoparticles with FCC structure. The nanoscale size and absence of impurity peaks demonstrate the effectiveness of the green synthesis approach using castor leaf extract.

The FT-IR spectrum confirms that bioactive compounds present in castor leaf extract (such as phenols, flavonoids, and proteins) play a dual role as reducing and stabilizing agents. The distinct Mn–O stretching band below 600 cm^{-1} verifies the successful synthesis of MnO nanoparticles, while other peaks indicate the presence of organic capping molecules on the nanoparticle surface.

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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