E-ISSN:2250-0758
P-ISSN:2394-6962
Research Article
Pilea-Microphylla

International Journal of Engineering and Management Research

2025 Volume 15 Number 3 June

Publisher
Vandana Publications
www.vandanapublications.com

Biogenesis and Characterization of Pilea-Microphylla Ferric Oxide Nanoparticles

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DOI:10.5281/zenodo.15803581

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Nanotechnology involves the manipulation of materials at the nanoscale, enabling their application across fields such as environmental remediation, medicine, and engineering. However, conventional nanoparticle synthesis methods often rely on toxic reducing agents like sodium borohydride, posing environmental and health risks. This research focuses on the eco-friendly synthesis of ferric oxide nanoparticles (Fe2O3NPs) using the plant extract Pilea microphylla, a herb rich in bioactive phytochemicals such as quercetin, luteolin, and apigenin derivatives. These phytochemicals act as natural reducing and capping agents, eliminating the need for hazardous chemicals. In this study, Pilea microphylla was processed into an aqueous extract and used to synthesize Fe2O3NPs from ferric nitrate. The reaction mixture was stirred with NaOH and centrifuged to collect the nanoparticles, which were subsequently calcined at 300–400°C. The synthesized Fe2O3NPs were characterized using X-ray Diffraction (XRD) and Field Emission Scanning Electron Microscopy (FESEM) to confirm particle size and morphology. The results demonstrate that plant-based synthesis offers a scalable, cost-effective, and sustainable approach to nanoparticle production, with potential applications in wastewater treatment and environmental remediation.

Keywords: Pilea-Microphylla, Iron Nanoparticles, Green Synthesis, XRD, FE SEM

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How to Cite this Article

Gaikwad D, Udekar P, Lohakare N, Lad V, Naik O, Patil S, Biogenesis and Characterization of Pilea-Microphylla Ferric Oxide Nanoparticles. Int J Engg Mgmt Res. 2025;15(3):32-35.
Available From
https://ijemr.vandanapublications.com/index.php/j/article/view/1763

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Manuscript Received	Review Round 1	Review Round 2	Review Round 3	Accepted
2025-05-06	2025-05-29			2025-06-16

Conflict of Interest	Funding	Ethical Approval	Plagiarism X-checker	Note
None	Nil	Yes	3.62	

1. Introduction

Nanotechnology refers to the capacity to observe, measure, manipulate, and fabricate materials at the atomic or molecular scale, typically between one and 100 nanometers. The notable surface area to volume ratio of these nanoscale materials is a critical attribute that facilitates their widespread application across diverse domains, including mechanics, optics, electronics, biotechnology, microbiology, environmental remediation, medicine, various engineering disciplines, and materials science [1]. Many of the initial techniques for generating well-defined iron nanoparticles involved their dispersion in mercury. Several mercury-based approaches were employed during the 1940s and 1950s, with some successfully adapted to procedures utilizing organic solvents. For instance, the reduction of salts to synthesize nanoparticles was conducted using amalgamated sodium, and this reduction process has since become a prevalent method for producing iron nanoparticles in organic solvents. Additionally, a method for producing iron via electrodeposition in mercury was patented in 1941 [2]. Nanoparticles produced through physical and chemical methods exhibit heightened toxicity due to the necessity of reducing agents such as sodium borohydride and hydrazine hydrate in their synthesis. These agents pose risks to both human health and the environment [3]. The advancement of environmentally sustainable methods for nanoparticle synthesis is crucial. Biological synthesis offers numerous advantages, including a clean and eco-friendly approach, the utilization of active biological compounds such as enzymes that serve as reducing and capping agents, the potential for large-scale production, and reduced energy consumption. A diverse array of biological sources, including microbes and plant materials, has been employed in this synthesis process [4]. The utilization of various adsorbents for adsorption is the most effective approach for treating wastewater contaminated with heavy metal ions. Due to iron's status as the second most abundant element on Earth, iron-based nanoparticles are significant among synthesized nanoparticles. Their importance arises from their magnetic properties, catalytic capabilities for pollutant removal in aquatic environments, cost-effectiveness, large surface area, extensive functionalization potential, high adsorption capacity for various contaminants in water and wastewater treatment, as well as their notable antimicrobial and antioxidant properties [5]. Numerous researchers have identified bioactive constituents within various herbs, spices, and plants that exhibit potent antioxidant properties, including amino acids, polyphenols, nitrogenous bases, and reducing sugars. These compounds serve as both capping agents and reducing agents in nanoparticle (NP) synthesis. Due to the vast diversity of plant species, it is possible to manipulate the morphology and size of the nanoparticles by selecting different plant extracts as sources. Furthermore, plant leaf extracts used in NP synthesis offer scalability for large-scale production while being economically viable. Metal and metal oxide nanoparticles synthesized using plant extracts generally maintain stability for over a month without exhibiting any noticeable changes [6]. *Pilea microphylla*, a prostrate herbaceous species adapted to humid environments, is commonly known as the artillery plant [7]. *Pilea microphylla* functions as a biologically derived substrate rich in essential phytochemicals, reducing the reliance on synthetic chemicals as capping, reducing, or stabilizing agents during the synthesis of nanoparticles from metal salt precursors. The bioactive phytochemicals present in *Pilea microphylla* include the following phenolic compounds:

1. Quercetin-3-O-rutinoside
2. 3-O-Caffeoylquinic acid
3. Luteolin-7-O-glucoside
4. Apigenin-7-O-rutinoside
5. Apigenin-7-O-β-d-glucopyranoside
6. Quercetin

These compounds act as natural capping agents, promoting the synthesis and stabilization of nanoparticles [8],[9]. In our latest research, we endeavored to synthesize Ferric oxide nanoparticles utilizing the plant extract *Pilea microphylla* and conducted a comprehensive characterization of the nanoparticles using X-ray Diffraction (XRD) and Field Emission Scanning Electron Microscopy (FESEM) to analyze particle size.

2. Materials & Method

All chemicals utilized in the synthesis were non-toxic. *Pilea microphylla* plants were collected from a rural region, and the whole herb was thoroughly washed with distilled water to eliminate residual sand particles. A total of 80 gm of the herb was grind into a uniform paste using a mortar and pestle.

This paste was dispersed in 100 ml of distilled water and boiled on a heating mantle for 15–20 minutes. After cooling, the extract was filtered using filter paper. In parallel, 20.2 gm of ferric nitrate was dissolved in 100 ml of distilled water to prepare a 0.5 M solution. The filtered plant extract (100 ml) was then mixed with the ferric nitrate solution (100 ml), yielding a final volume of 200 ml. The mixture was placed on a magnetic stirrer and stirred for 1–2 hours, during which 1–3 drops of NaOH solution were added to facilitate the reaction. Following stirring, the mixture was transferred to centrifuge tubes and centrifuged at appropriate speeds for 30–45 minutes. The collected precipitate was carefully transferred to a crucible and subjected to calcination in a muffle furnace at 300–400°C to obtain the final product.

3. Result & Discussions

X-Ray Diffraction Analysis (XRD):

Elemental analysis and chemical characterization of green synthesized Ferric oxide nanoparticles from *Pilea microphylla* was analysed by X-Ray diffraction spectroscopy.

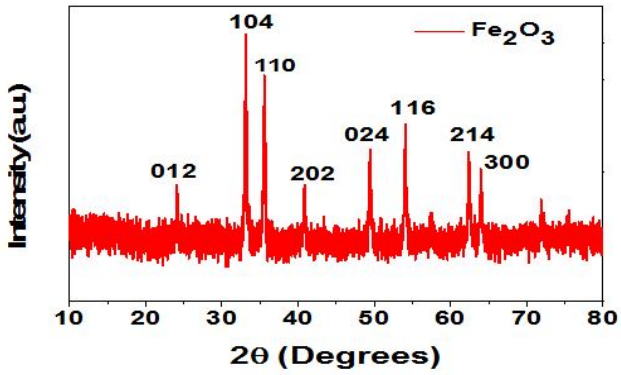

Figure 1

Fig. 1. Shows the XRD analysis was used to investigate the crystalline structure of the synthesized Fe_2O_3 sample. The diffraction peaks at 2θ = 24.11o, 33.13o, 35.58o, 40.82o,49.18o, 54.05o, 62.43o and 63.98o correspond to the diffraction planes of (012), (104), (110), (202), (024), (116), (214) and (300). These peaks corresponded to the rhombohedral Fe_2O_3 sample (JCPDS: 33-0664) [01]. A moderate XRD scan was used to estimate the crystallite size (d) of sample Fe_2O_3. The average grain size was 25.35 nm.

Field Emission Scanning Electron Microscopy (FE-SEM):

The FE-SEM study of Fe_2O_3NPs revealed the morphological homogeneity in the distribution of Fe_2O_3NPs on the grid surface. FE-SEM shows an abundance of nanoparticles with a variety of morphologies, though spherical NPs of different sizes tend to predominate. The size of the synthesized Fe_2O_3NPs ranged between 24.11 nm and 63.98 nm

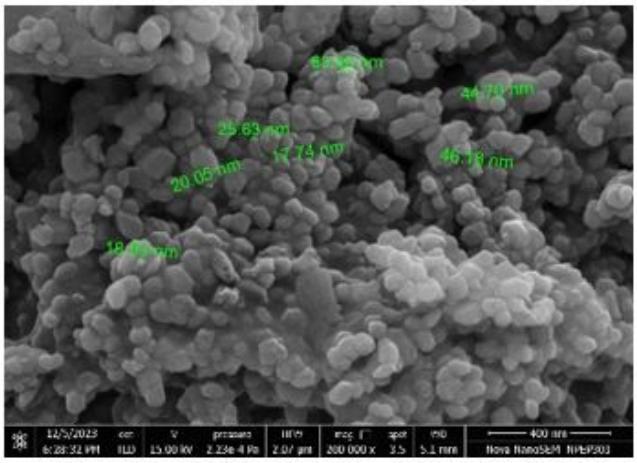

Figure 2 a)

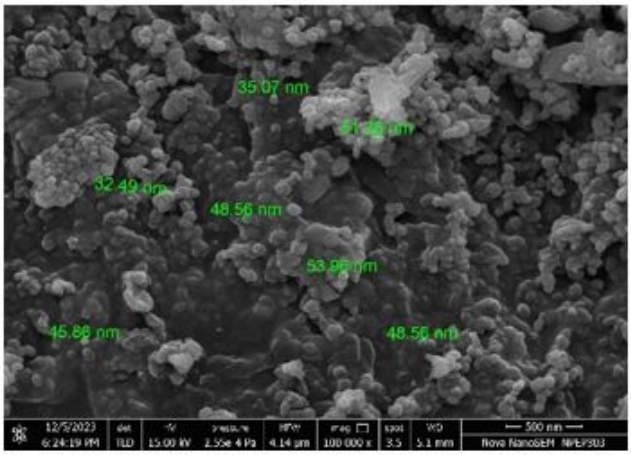

Figure 2 b)

4. Conclusion

Ferric oxide nanoparticles were successfully synthesized by using *pilea microphylla* plant extract, X-Ray Diffraction (XRD) Spectroscopy shows the diffraction peak of Fe_2O_3 NPs at 2θ = 24.11o, 33.13o, 35.58o, 40.82o,49.18o, 54.05o, 62.43o and 63.98o. Field emission scanning electron microscopy (FE-SEM) shows the size of the synthesized Fe_2O_3NPs ranged between 24.11 nm and 63.98 nm

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