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Green Synthesized MgO Nanoparticles from Vigna Radiata Seed Peel: Structural, Morphological and Elemental Insights

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Abstract: *Nanotechnology focuses on materials engineered at the nanoscale, where at least one dimension falls between 1 and 100 nanometers. Because of their minute size, these materials possess an immense surface area relative to their volume, triggering unique quantum effects that dramatically alter their electrical, optical, and chemical properties. These enhanced capabilities have unlocked breakthroughs in practical applications, ranging from medical diagnostics and cosmetics to aerospace components, biosensors, and advanced electronics. [1,2]. The enhanced stability, mechanical strength, and functional properties of nanomaterials have further increased their importance in advanced technological applications [3].*

Due to their exceptional structural and chemical versatility, magnesium oxide nanoparticles (MgO NPs) stand out among contemporary metal oxide nanomaterials. Economically viable and highly recyclable, MgO NPs combine low density and robust strength-to-weight ratios with remarkable thermal stability and hygroscopic properties. Furthermore, their inherent biocompatibility and biodegradability make them highly attractive for in vivo systems. [4] Driven by intense surface reactivity, these nanoparticles serve as critical components in fields ranging from environmental catalysis and sensor development to antimicrobial agents and advanced energy technologies.

Keywords: Green Synthesized MgO Nanoparticles from Vigna radiata Seed Peel: Structural, Morphological and Elemental Insights

I. INTRODUCTION

Nanotechnology focuses on materials engineered at the nanoscale, where at least one dimension falls between 1 and 100 nanometers. Because of their minute size, these materials possess an immense surface area relative to their volume, triggering unique quantum effects that dramatically alter their electrical, optical, and chemical properties. These enhanced capabilities have unlocked breakthroughs in practical applications, ranging from medical diagnostics and cosmetics to aerospace components, biosensors, and advanced electronics. [1,2]. The enhanced stability, mechanical strength, and functional properties of nanomaterials have further increased their importance in advanced technological applications [3].

Due to their exceptional structural and chemical versatility, magnesium oxide nanoparticles (MgO NPs) stand out among contemporary metal oxide nanomaterials. Economically viable and highly recyclable, MgO NPs combine low density and robust strength-to-weight ratios with remarkable thermal stability and hygroscopic properties. Furthermore, their inherent biocompatibility and biodegradability make them highly attractive for in vivo systems. [4] Driven by intense surface reactivity, these nanoparticles serve as critical components in fields ranging from environmental catalysis and sensor development to antimicrobial agents and advanced energy technologies.

Nanoparticle fabrication historically relies on established synthetic routes such as sol–gel transitions, chemical reduction, thermal degradation, or physical deposition. While effective, these traditional protocols frequently demand substantial energy inputs, cost-intensive precursors, and aggressive reagents that yield environmentally hazardous effluents. To mitigate these ecological impacts, green synthesis has emerged as a viable, economically favorable paradigm. This bio-assisted approach leverages the metabolic machinery of microorganisms, plant extracts, or biopolymers. Within these natural matrices, functional biomolecules—including phenolic compounds, flavonoids, carbohydrates, and proteins—simultaneously serve as the reductive engines, stabilizing matrices, and capping ligands required to control nanoparticle growth. [5].

Several researchers have reported the green synthesis of MgO nanoparticles using plant-based extracts. Umar Ali Khan et al. demonstrated the environmentally friendly synthesis of MgO nanoparticles using *Psidium guajava* and *Aloe vera* leaf extracts and reported significant antibacterial activity against *Staphylococcus aureus* and *Escherichia coli* [6]. Nisa et al. investigated the antioxidant properties of MgO nanoparticles, while Shanmugapriya and Fadhila reported the antioxidant potential of *Acalypha indica* extract, suggesting enhanced biological activity through nanoparticle–plant interactions [7–9].

Vigna radiata (mung bean), belonging to the Fabaceae family, is an important leguminous crop widely used as a nutritional food source. Its seed peel, generated as an agricultural waste material during food processing, contains several phytoconstituents including polyphenols, flavonoids, phenolic acids, tannins, peptides, sugars, and other bioactive compounds. These phytochemicals possess excellent reducing and stabilizing properties, making *Vigna radiata* peel extract a promising biological resource for nanoparticle synthesis. Recent studies have reported successful green synthesis of different metal and metal oxide nanoparticles using *Vigna radiata* extracts [10–13].

The utilization of agricultural waste for nanoparticle synthesis provides an eco-friendly and economical approach while supporting waste valorization and sustainable development. In the present study, MgO nanoparticles were synthesized using *Vigna radiata* seed peel extract through a green synthesis route. The synthesized nanoparticles were characterized using X-ray diffraction (XRD), scanning electron microscopy (SEM), and energy dispersive X-ray spectroscopy (EDX) to investigate their structural, morphological, and elemental properties. The proposed synthesis method minimizes the use of hazardous chemicals and relies on naturally occurring phytochemicals present in the seed peel extract as reducing and stabilizing agents. This environmentally benign approach highlights the potential of *Vigna radiata* seed peel as an effective bio-resource for the preparation of MgO nanoparticles with promising applications in catalysis, antimicrobial systems, and environmental remediation.

II. MATERIALS AND METHODS

2.1 Materials

Magnesium precursor salt (magnesium nitrate/magnesium acetate) was used as the source of magnesium ions. *Vigna radiata* seed peels were collected, washed thoroughly with distilled water, dried, and used for preparation of plant extract. All chemicals used were of analytical grade.

2.2 Preparation of *Vigna radiata* Seed Peel Extract

Collected seed peels were washed several times with distilled water to remove impurities and dried under shade. The dried material was finely powdered. A suitable quantity of powder was boiled in distilled water for approximately 20–30 minutes to extract bioactive compounds. The extract was filtered and stored for further synthesis.

2.3 Green Synthesis of MgO Nanoparticles

The prepared *Vigna radiata* peel extract was added slowly to the magnesium salt solution under continuous stirring. The reaction mixture was maintained under controlled alkaline conditions using sodium hydroxide to facilitate nanoparticle formation. The appearance of yellow color turbidity indicated the formation of magnesium-containing nanoparticles.

The obtained precipitate was separated by filtration and washed repeatedly with distilled water to remove impurities. The product was dried and subjected to calcination at 450ºC to obtain crystalline magnesium oxide nanoparticles.
The possible formation mechanism can be represented as:

Mg^{2+} + Plant phytochemicals → $Mg(OH)_2$ → MgO nanoparticles

The phytoconstituents present in the peel extract act as stabilizing and capping agents during nanoparticle formation.

III. CHARACTERIZATION TECHNIQUES

3.1 X-ray Diffraction (XRD)

The crystalline structure of synthesized MgO nanoparticles was analyzed using X-ray diffraction. The diffraction pattern was recorded using Cu Kα radiation. The obtained diffraction peaks were compared with standard MgO diffraction data.
The crystallite size was calculated using the Debye–Scherrer equation [14]:

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

where:
D = crystallite size
K = Scherrer constant
λ = wavelength of X-ray radiation
β = full width at half maximum
θ = Bragg diffraction angle

3.2 Scanning Electron Microscopy (SEM)

Surface morphology and particle characteristics were examined using SEM analysis. The SEM images provided information regarding particle shape, aggregation, and surface texture.

3.3 Energy Dispersive X-ray Spectroscopy (EDX)

EDX analysis was performed to determine elemental composition and confirm the presence of magnesium and oxygen elements in the synthesized nanoparticles.

IV. RESULTS AND DISCUSSION

4.1 XRD Analysis

The XRD pattern of synthesized MgO nanoparticles exhibited characteristic diffraction peaks corresponding to the cubic phase of magnesium oxide. The observed peaks confirmed the formation of crystalline MgO with a face-centered cubic structure.
The diffraction peaks corresponded to the characteristic planes of MgO, including (111), (200), and (220) planes. No additional impurity peaks were observed, indicating high purity of the synthesized material.
The average crystallite size calculated using the Debye–Scherrer equation was approximately 46.3 nm, confirming nanoscale formation.
The crystallinity of MgO nanoparticles can be attributed to the thermal conversion process during calcination, which promotes rearrangement of magnesium and oxygen ions into a stable crystalline lattice.
XRD analysis XRD analysis was performed using the CuKα radiation in the range of 30–80° (2θ). Figure 1 shows the XRD analysis of green synthesized MgO NPs by Vigna radiata seed peel powder. The XRD peak contains 27.443°, 31.771°, 42.926°, 45.511° and 62.264°are corresponding 2θ values. A peak is observed in the XRD spectrum around (200) for 2θ value 42.926°and (220) for 2θ value 62.264° which prove the high crystallinity of MgO NPs.
The calculated average crystalline size for the obtained MgO NPs was 46.3 nm, and the computed lattice constant of MgO NPs is 4.2133Å.

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Among these, the prominent diffraction peaks at 42.926° (200 plane) and 62.264° (220 plane) are characteristic of MgO's face-centered cubic (fcc) structure and serve as strong evidence of high crystallinity. The sharpness and intensity of these reflections indicate that the nanoparticles possess well ordered atomic arrangements with minimal structural distortions. The average crystallite size, calculated using the Debye–Scherrer equation, was found to be 46.3 nm.

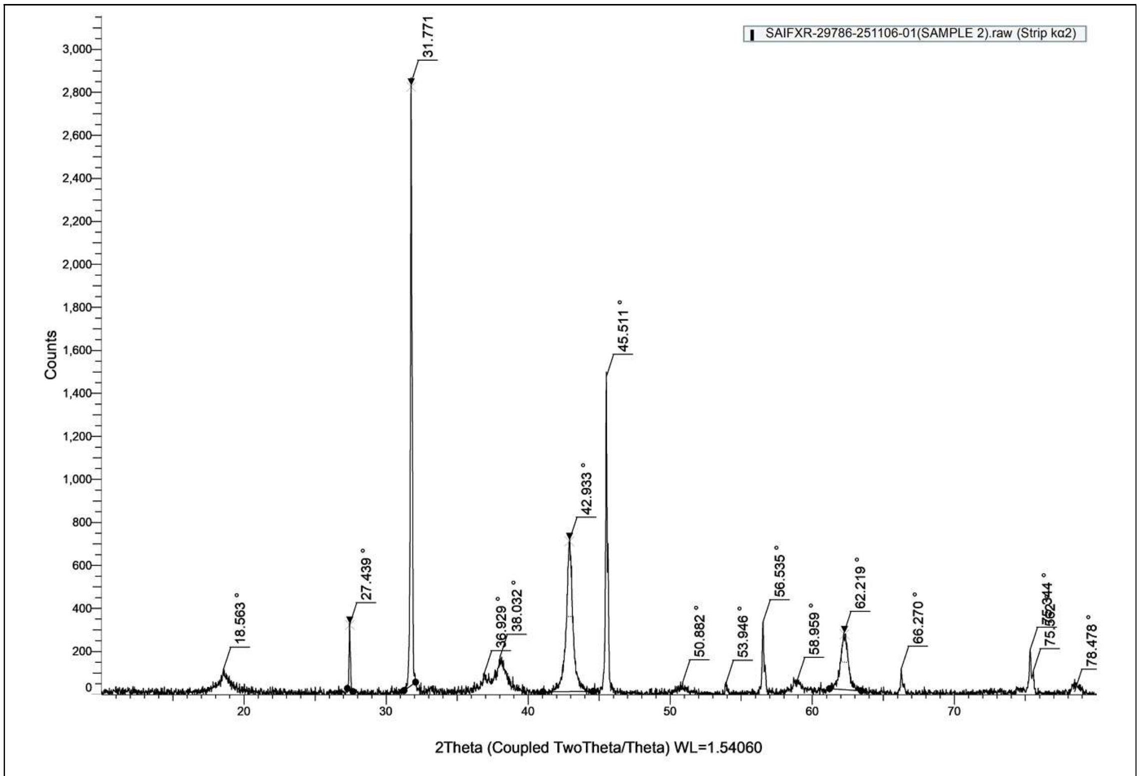

Figure 1: XRD graph of MgONPs from *Vigna radiata* peel powder

4.2 SEM Morphological Analysis

The SEM micrograph of the green-synthesized MgO nanoparticles reveals important information about the surface morphology and structural features of the nanoparticles formed using Vigna radiata seed peel extract. The image, captured at 1500× magnification, shows a heterogeneous morphology dominated by aggregated nanosized particles. Particle aggregation is commonly observed in metal oxide nanoparticles due to strong surface interactions and high surface energy at the nanoscale.

In plant-mediated synthesis, phytochemicals such as phenols, flavonoids, and tannins serve as both reducing and stabilizing agents. [15]

The porous morphology obtained through green synthesis may contribute to improved surface-dependent applications such as pollutant removal and antimicrobial activity.

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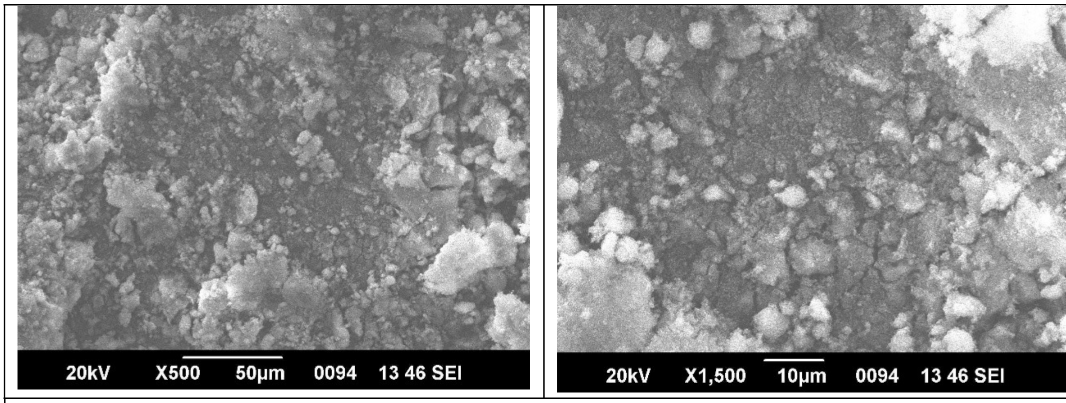

Figure 2: Scanning electron microscopy (SEM) image of MgONP's

4.3 EDX Elemental Analysis

EDX spectrum confirmed the elemental composition of synthesized nanoparticles. The presence of magnesium and oxygen peaks verified the successful formation of MgO nanoparticles.

The absence of significant impurity elements indicates that the biological synthesis route produced relatively pure nanoparticles. Minor signals, if present, may originate from organic residues associated with plant-based capping molecules.

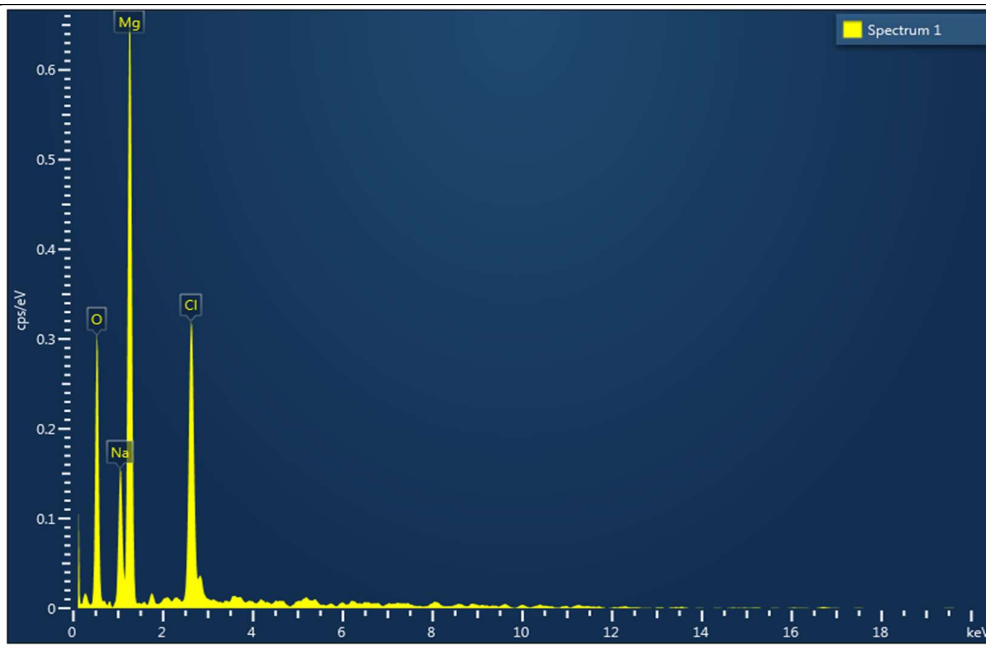

Figure 3: EDX analysis of MgONPs from *Vigna radiata* peel powder

Tabel 1: The percentage of trace elements present in MgONP's from *Vigna radiata* seed peel powder

Element	Line Type	Wt%	Atomic %
O	K series	38.26	50.77
Na	K series	8.7	8.03

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Mg	K series	34.42	30.05
Cl	K series	18.62	11.15
Total:		100	100

V. PROPOSED MECHANISM OF GREEN SYNTHESIS

The phytochemicals present in *Vigna radiata* seed peel extract play an important role in nanoparticle formation. Phenolic compounds and flavonoids donate electrons, facilitating conversion of magnesium ions into magnesium hydroxide intermediates. Subsequent thermal treatment results in dehydration and formation of MgO nanoparticles.

The biological molecules also prevent excessive particle growth by acting as natural stabilizing and capping agents.

VI. POTENTIAL APPLICATIONS

The synthesized MgO nanoparticles possess several desirable characteristics including crystallinity, nanoscale size, and porous morphology. These properties make them suitable candidates for:

- Antimicrobial applications due to MgO-induced oxidative stress mechanisms.
- Catalytic processes owing to high surface activity.
- Environmental remediation including adsorption and degradation of pollutants.
- Development of advanced functional materials.

Figure 4: Zone of inhibition zone of MgO NPs of *Vigna radiata* peel powder shown by a) *E. coli*, b) *S . aureus* and c) *P. aeruginosa*

Table 1: Showing antibacterial inhibition zone of MgO NPs of *Vigna radiata* peel powder.

Sr. No.	Name of organism	Zone of Inhibition values in mm			
		25 µl/ml	50 µl/ml	75 µl/ml	100 µl/ml
1	*E. coli*	15mm	16mm	15mm	14mm
2	*S. aureus*	26mm	25mm	25mm	25mm
3	*P. aeruginosa*	20mm	20mm	19mm	18mm

The results obtained from the studies were shown photographically as well as in Table 1. The zone of inhibition for various organisms were calculated. A significant result was obtained for *Pseudomonas aeruginosa*, *Staphylococcus aureus* and *Escherichia coli.*

The antibacterial activity of MgO nanoparticles (MgO NPs) synthesized using *Vigna radiata* peel powder was evaluated against E. coli, S. aureus, and P. aeruginosa by measuring the zone of inhibition at different concentrations (25–100 µl/ml).

The results indicate that the synthesized MgO NPs exhibited antibacterial activity against all tested bacterial strains. Among them, S. aureus showed the highest susceptibility, with inhibition zones ranging from 25–26 mm, suggesting strong antibacterial effectiveness against this Gram-positive bacterium. The maximum inhibition (26 mm) was observed at 25 µl/ml, and the values remained nearly constant at higher concentrations.

P. aeruginosa showed moderate sensitivity with inhibition zones between 18–20 mm. The inhibition remained stable at lower concentrations and showed a slight reduction as concentration increased.

E. coli exhibited the lowest antibacterial response, with inhibition zones ranging from 14–16 mm. The highest inhibition (16 mm) was observed at 50 µl/ml, followed by a slight decline at higher concentrations.

Overall, no concentration-dependent increase in antibacterial activity was observed. Instead, the inhibition zones remained relatively stable or slightly decreased with increasing concentration. This may suggest that lower concentrations of MgO NPs were already sufficient to exert antibacterial effects, and further increase in concentration did not enhance bacterial growth inhibition. The stronger activity against S. aureus compared with Gram-negative bacteria (E. coli and P. aeruginosa) may be associated with differences in bacterial cell wall structure, where the outer membrane of Gram-negative bacteria can reduce nanoparticle penetration and antibacterial action.

VI. CONCLUSION

The present investigation demonstrates a simple, economical, and environmentally friendly approach for the synthesis of magnesium oxide nanoparticles using *Vigna radiata* seed peel extract. The utilization of agricultural waste as a biological resource provides an effective pathway towards sustainable nanomaterial production.

Structural analysis confirmed the formation of highly crystalline MgO nanoparticles with a cubic face-centered structure and an average crystallite size of 46.3 nm. SEM analysis revealed aggregated granular and porous morphology, while EDX confirmed the presence of magnesium and oxygen as major constituents.

In summary, MgO nanoparticles (MgO NPs) synthesized using *Vigna radiata* peel powder exhibited antibacterial activity against all tested bacteria. The highest inhibition was observed against *S. aureus* (25–26 mm), followed by *P. aeruginosa* (18–20 mm) and *E. coli* (14–16 mm). The antibacterial effect remained relatively stable across concentrations, indicating effective activity even at lower doses.

The findings highlight the potential of *Vigna radiata* seed peel as a valuable bio-resource for green synthesis of MgO nanoparticles with promising applications in catalysis, antimicrobial technology, and environmental remediation.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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