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# Green Synthesis of Magnesium Oxide Nanoparticles using *Trigonella Foenum-Graecum* Seeds Extract

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**ABSTRACT:** Chemical synthesis of nanoparticles often involves hazardous chemicals, which pose significant environmental and health risks. As a sustainable alternative, green synthesis utilizes phytochemicals present in plants, which act as effective reducing and stabilizing agents. In the present study, magnesium oxide (MgO) nanoparticles were synthesized using a green route employing *Trigonella foenum-graecum* (fenugreek) seed extract. The biosynthesized MgO nanoparticles were characterized using various techniques. X-ray diffraction (XRD) confirmed the crystalline structure and estimated crystallite size. Scanning electron microscopy (SEM) revealed surface morphology, while energy dispersive X-ray analysis (EDAX) confirmed the elemental composition and purity. The results suggest that the green synthesis route is effective for producing MgO nanoparticles with desirable properties. These nanoparticles hold potential for further evaluation of their antimicrobial activity, with promising applications in biomedical and environmental fields.

**KEYWORDS:** Green synthesis, MgO nanoparticles, *Trigonella foenum-graecum*, FTIR spectroscopy, XRD analysis, SEM imaging

## I. INTRODUCTION

The development of environmentally sustainable methods for nanoparticle synthesis has emerged as a crucial branch of nanotechnology. In recent years, significant progress has been made in the green synthesis of nanoparticles using biological extracts derived from unicellular organisms such as bacteria and fungi, as well as from various parts of plants[1]. Although numerous chemical methods are available for the synthesis of metal nanoparticles, these typically involve the use of toxic reactants and hazardous starting materials. Growing environmental concerns associated with conventional chemical routes have driven the pursuit of biomimetic approaches for nanoparticle fabrication[2].

Magnesium oxide (MgO), a widely used inorganic metal oxide, possesses several desirable properties, including a wide band gap, high thermal stability, low dielectric constant, and low refractive index[3]. It is recognized as a safe material for human use, and in the medical field, MgO is commonly used as an antacid to treat heartburn and upset stomachs. Therefore, from a biomedical perspective, the green synthesis of biocompatible magnesium oxide nanoparticles (MgO NPs) offers promising potential [4].

Despite their advantages, the biological synthesis of MgO NPs remains relatively underexplored. The unique properties of nanomaterials have spurred extensive research into their synthesis, characterization, and applications [5]. Several conventional techniques exist for the synthesis of metal oxide nanoparticles, including solution combustion, co-precipitation, sol-gel, hydrothermal, solvothermal, and microwave-assisted sol-gel methods. Among these, green synthesis stands out as a cost-effective and eco-friendly alternative, requiring fewer toxic chemicals and producing environmentally benign by-products [6].

## II. LITERATURE SURVEY

Metal oxide nanoparticles (MONPs) such as zinc oxide (ZnO), copper oxide (CuO), cobalt oxide (CoO), and magnesium oxide (MgO) have garnered significant interest due to their unique physicochemical properties and wide range of applications. Their high surface area-to-volume ratio, tunable optical and electronic characteristics, and catalytic activity make them valuable in fields such as medicine, environmental remediation, energy storage, and electronics. ZnO nanoparticles are widely used for their antimicrobial, UV-blocking, and semiconductor properties,

making them suitable for sunscreens, sensors, and photocatalysts [7,8,9]. CuO nanoparticles are known for their antimicrobial, catalytic, and conductive properties, finding use in batteries, gas sensors, and antifouling coatings [10]. CoO nanoparticles exhibit magnetic and electrochemical characteristics, making them promising for lithium-ion batteries, supercapacitors, and biomedical applications [11]. MgO nanoparticles, on the other hand, are favored for their biocompatibility, high thermal stability, and antimicrobial properties, making them useful in drug delivery, catalysis, and wastewater treatment. The versatility and functional tunability of these metal oxide nanoparticles position them as key materials in advancing nanotechnology-enabled solutions across diverse sectors. Green synthesis of magnesium oxide nanoparticles (MgO-NPs) using plant extracts has gained substantial attention due to its eco-friendly, cost-effective, and biocompatible nature. Various plant parts including leaves, peels, fruits, and heartwood have been successfully used as reducing and stabilizing agents due to the rich presence of phytochemicals such as flavonoids, terpenoids, tannins, and phenolics. J. Suresh et al. [12] synthesized MgO-NPs using *Nephelium lappaceum* (rambutan) peel extract, yielding nanoparticles sized between 60–70 nm. Rambutan, a tropical fruit of the *Sapindaceae* family, is known for its medicinal uses, with its roots, bark, and leaves applied in traditional medicine and dye production. Similarly, R. Prasanth et al. [13] utilized *R. lamarckii* leaf extract to synthesize MgO-NPs with nano-hexagonal and spherical morphology, ranging between 20–50 nm and showing crystalline nature. Mary Vergeese et al. [14] reported successful synthesis of MgO-NPs using *Trigonella foenum-graecum* (fenugreek) leaf extract. Mohammad Isa Khan et al. [15] used *Dalbergia sissoo* (Sheesham) extract to fabricate MgO-NPs with promising photocatalytic and antibacterial properties. *D. sissoo* is a well-known medicinal plant rich in biomolecules such as sissoic acid, quercetin-3-O-rutinoside, kaempferol-3-O-rutinoside, dalsissoside, and iochanin A, which act as effective reducing and stabilizing agents. Furthermore, mutagenic and cytotoxicity profiling confirmed the extract to be non-toxic and non-mutagenic, aligning with the principles of green chemistry. Abdul Muhaymin et al. [16] achieved green synthesis of MgO-NPs using fruit extract of the gingerbread tree (*Hyphaene thebaica*). Ajay Singh et al. [17] used *Rhododendron arboreum* leaf extract to synthesize MgO-NPs in a cost-effective and efficient manner. P. Sugirtha et al. [18] conducted comparative studies using aqueous extracts of cauliflower (*Brassica oleracea*) and pomegranate (*Punica granatum*) peels. Pomegranate peels are rich in polyphenols, flavonoids, and tannins such as gallic acid and ellagic acid, which have therapeutic and antioxidant properties. Cauliflower contains glucosinolates, anthocyanins, and indole-3-carbinol, all of which contribute to its antioxidant and anticancer activity. Rand Ali et al. [19] synthesized MgO-NPs using persimmon (*Diospyros kaki*) peel extract, which is typically considered waste but contains valuable bioactive compounds such as tannins, flavonoids, terpenoids, and carotenoids. Manne Anupama Ammulu et al. [20] employed aqueous heartwood extract of *Pterocarpus marsupium*, rich in polyphenolics and flavonoids, for eco-friendly synthesis of MgO-NPs. Mozafar Khazaei et al. [21] synthesized MgO-NPs using *Falcaria vulgaris* extract for evaluating their effectiveness in burn wound treatment in rats. Kiran S. et al. [22] reported MgO-NP synthesis using aqueous leaf extract of *Iresine herbstii*. Gaurav Sharma et al. [23] employed *Swertia chirayita* extract, yielding spherical MgO-NPs of <20 nm size, highlighting the role of medicinal plant material as both reducing and capping agent in nanoparticle formation. Enobong R. Essien [24] synthesized MgO-NPs using aqueous leaf extract of *Manihot esculenta*. El-Shimaa M.A. Galal et al. [25] reported MgO-NP formation using *Hyoscyamus muticus* leaf extract. Abel Saka et al. [26] used *Datura stramonium* leaves for MgO-NP synthesis via both chemical and biological methods. Finally, S. Krishna Moorthy et al. [27] successfully synthesized MgO nanoparticles using *Azadirachta indica* (Neem) leaf extract, known for its wide-ranging medicinal value. The wet chemical method is a commonly employed technique for the synthesis of magnesium oxide nanoparticles (MgO-NPs) [28]. However, plant-mediated green synthesis is increasingly gaining prominence as a sustainable alternative, aiming to minimize the use of harsh and toxic chemicals typically involved in conventional methods [29]. These studies collectively highlight the diversity and efficacy of plant-based green synthesis approaches in generating MgO nanoparticles, offering promising avenues for scalable, sustainable nanomaterial production.

In the present work, methi (fenugreek) seed extract is utilized as a green reducing and stabilizing agent for the synthesis of magnesium oxide nanoparticles. *Trigonella foenum-graecum*, commonly known as fenugreek, is an annual plant belonging to the *Fabaceae* family. The plant features trifoliate leaves composed of three small obovate to oblong leaflets. It is cultivated widely across the globe and is recognized for its medicinal properties. Fenugreek seeds are known to regulate blood lipid levels and reduce blood sugar in diabetic patients. Additionally, they exhibit significant antioxidant and antibacterial activities. The seeds are rich in various bioactive phytoconstituents, including alkaloids, amino acids, flavonoids, steroids, steroidal saponins, dietary fibers, saponins, lipids, polyphenols, and carbohydrates. These compounds play a crucial role in the green synthesis of nanoparticles by acting as natural reducing, capping, and stabilizing agents.

### III. METHODOLOGY

#### Materials and methods

*Trigonella foenum-graecum* (methi seeds) functions as a reducing and stabilizing agent and the precursor is magnesium Nitrate. Methi seeds were purchased from the local market. Magnesium oxide (MgO) nanoparticles were synthesized using magnesium nitrate hexahydrate ( $\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$ ) as the precursor salt and sodium hydroxide (NaOH) as the precipitating agent, following a green synthesis approach involving *Trigonella foenum-graecum* (fenugreek) seed extract.

#### Synthesis of methi seed extract

5 g of fenugreek seed powder was boiled in 125 mL of distilled water to prepare a concentrated plant extract. The resulting solution was allowed to cool and then filtered through Whatman filter paper to obtain a clear extract rich in phytochemicals.

#### Synthesis of magnesium oxide nanoparticles

Approximately 38.46 g of  $\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$  was accurately weighed and dissolved in 150 mL of distilled water in a 250 mL conical flask. In a separate beaker, 2 g of NaOH was dissolved in 50 mL of distilled water. The magnesium nitrate solution was heated to 72 °C while continuously stirred using a magnetic stirrer. The NaOH solution was then added dropwise along the walls of the flask using a pipette, under continuous stirring. This controlled addition ensured uniform mixing and minimized sudden pH fluctuations. This filtered extract was subsequently added to the magnesium nitrate–NaOH mixture. The formation of white precipitate indicated the initiation of MgO nanoparticle synthesis, likely mediated by the bioactive compounds present in the extract. After the complete addition of the NaOH solution, the magnetic stirring was stopped, and the reaction mixture was left undisturbed at room temperature for approximately 20 hours to allow complete precipitation. The resulting precipitate was separated from the supernatant by centrifugation and collected in a clean Petri dish. The sample was then subjected to mild heating on a hot plate for 3–4 hours, during which the precipitate gradually transformed into a powder form. Magnesium oxide powder was kept on calcination at 800 °C so that the impurities & volatile substance could be removed from that compound.

#### Mechanism of green synthesis of Magnesium oxide nanoparticles

The green synthesis of magnesium oxide (MgO) nanoparticles proceeds through a three-step mechanism: activation, growth, and termination. In the activation phase, metal ion reduction and nucleation are initiated. Phytochemicals present in the plant extract particularly flavonoids possess abundant hydroxyl groups and electron-rich aromatic systems that facilitate redox reactions. These compounds chelate with  $\text{Mg}^{2+}$  ions, and through tautomeric transformation from the enol to keto form, they release reactive hydrogen species. These species act as reducing agents, converting  $\text{Mg}^{2+}$  ions into elemental magnesium ( $\text{Mg}^0$ ). Concurrently, the nucleation of MgO occurs as oxygen species in the reaction medium oxidize  $\text{Mg}^0$ , forming MgO nuclei. The nucleation stage involves the aggregation of these reduced atoms into nanoclusters, which serve as thermodynamically unstable nucleation sites. These clusters are highly reactive and form the primary seeds for particle development. Transitioning into the growth phase, Ostwald ripening and oriented attachment mechanisms govern the enlargement of nuclei into well-defined nanoparticles. This phase is significantly influenced by reaction parameters such as precursor concentration, phytochemical content, pH, temperature, and residence time, which collectively determine particle size, morphology, crystallinity, and surface energy.

Finally, during the termination phase, nanoparticle growth stabilizes as the availability of reactive ions diminishes. The surface of the nanoparticles becomes passivated by capping agents phytoconstituents such as saponins, tannins, and flavonoids forming a protective organic layer that prevents agglomeration. This bio-capping confers colloidal stability, enhances biocompatibility, and may modulate the nanoparticles' surface reactivity, making them suitable for downstream applications in catalysis, biomedicine, and environmental remediation.

### IV. EXPERIMENTAL RESULTS

X-ray diffraction (XRD) analysis of the synthesized magnesium oxide (MgO) nanoparticles was performed using a PANalytical X-ray diffractometer equipped with a Cu  $K\alpha$  radiation source ( $\lambda = 1.5406 \text{ \AA}$ ). The scan was conducted in continuous mode over a  $2\theta$  range of 9.999° to 79.979°, with a step size of 0.020° and a step time of 1 second per point. The measurements were carried out at room temperature (25 °C) along the goni scan axis. The instrument was

configured with a fixed divergence slit of  $1.0^\circ$  and a receiving slit size of 0.1 mm. The goniometer radius was 240 mm, and the sample was not spun during the scan. No incident beam monochromator was used. The diffraction data were processed using HighScore Plus software (PANalytical), which included background subtraction via automatic correction and  $K\alpha_2$  stripping using the Rachinger method. The phase purity and crystalline nature of the synthesized magnesium oxide (MgO) nanoparticles were analyzed using X-ray diffraction (XRD). The diffraction pattern revealed five prominent peaks at  $2\theta$  values of  $31.30^\circ$ ,  $43.43^\circ$ ,  $62.77^\circ$ ,  $75.03^\circ$ , and  $78.96^\circ$ , with

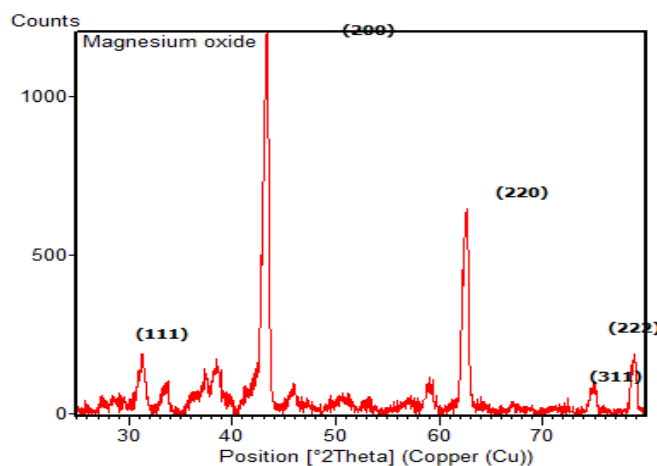


Figure 2: X ray diffraction graph of synthesized magnesium oxide nanoparticles

corresponding relative intensities of 14.61, 100.00, 49.98, 7.17, and 14.58, respectively. These peaks were indexed to the (111), (200), (220), (311), and (222) planes of the face-centered cubic (FCC) structure of MgO, in accordance with JCPDS card no. 89-7746. The most intense peak at  $43.43^\circ$  corresponds to the (200) plane, indicating a preferred orientation along this crystallographic direction. The sharp and narrow peaks reflect the high crystallinity of the synthesized nanoparticles. Furthermore, the absence of additional impurity peaks confirms the formation of phase-pure MgO. The crystallite size of the nanoparticles can be estimated using the Debye–Scherrer formula, provided the full width at half maximum (FWHM) is known.

Table 1: XRD data of synthesized magnesium oxide nanoparticles

Pos. [ $2\theta$ .]	Height [cts]	FWHM [ $2\theta$ .]	Left	d-spacing [ $\text{\AA}$ ]	Rel. Int. [%]
31.298660	156.921500	0.672000		2.85561	14.61
43.433850	1074.045000	0.768000		2.08177	100.00
62.770130	536.814900	0.528000		1.47911	49.98
75.026230	76.995280	0.864000		1.26498	7.17
78.964690	156.561500	0.768000		1.21147	14.58

Morphological studies were done by scanning electron microscope. The above figure shows the SEM images of magnesium oxide nanoparticles taken at different magnifications.

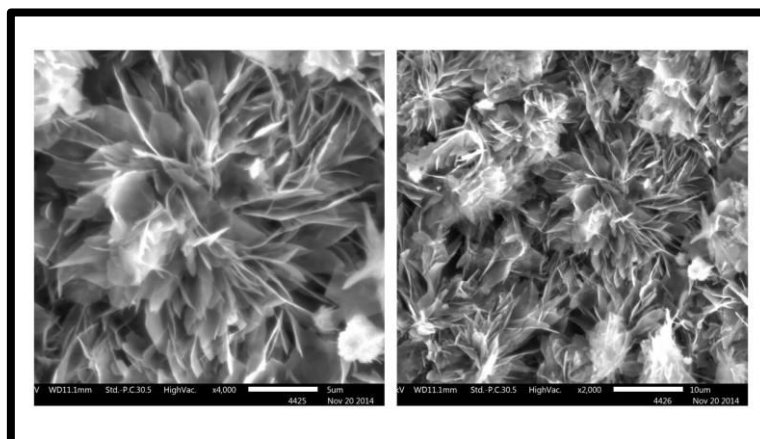


Figure 3: Scanning electron microscopy images of synthesized magnesium oxide nanoparticles

## V. CONCLUSION

The present study successfully demonstrates the green synthesis of magnesium oxide (MgO) nanoparticles using *Trigonella foenum-graecum* (fenugreek) seed extract as a reducing and stabilizing agent. The phytochemicals present in the methi extract facilitated the bio-reduction of magnesium nitrate and contributed to the formation of stable, crystalline MgO nanoparticles. Characterization through XRD confirmed the face-centered cubic structure and high crystallinity of the synthesized nanoparticles, while SEM analysis revealed microflower-like morphological features. This eco-friendly and cost-effective approach eliminates the need for toxic chemicals and harsh reaction conditions, aligning well with the principles of green chemistry. The synthesized TMgO nanoparticles hold promise for applications in biomedical, environmental, and catalytic fields due to their biocompatibility and purity. Future studies may focus on evaluating their antimicrobial efficacy and exploring their performance in real-world applications.

## VI. FUTURE SCOPE

The present study successfully demonstrates the green synthesis of magnesium oxide (MgO) nanoparticles using *Trigonella foenum-graecum* (fenugreek) seed extract as a reducing and stabilizing agent. The phytochemicals present in the methi extract facilitated the bio-reduction of magnesium nitrate and contributed to the formation of stable, crystalline MgO nanoparticles. Characterization through XRD confirmed the face-centered cubic structure and high crystallinity of the synthesized nanoparticles, while SEM analysis revealed microflower-like morphological features. This eco-friendly and cost-effective approach eliminates the need for toxic chemicals and harsh reaction conditions, aligning well with the principles of green chemistry. The synthesized TMgO nanoparticles hold promise for applications in biomedical, environmental, and catalytic fields due to their biocompatibility and purity. Future studies may focus on evaluating their antimicrobial efficacy and exploring their performance in real-world applications.

The green synthesis of MgO nanoparticles using *Trigonella foenum-graecum* seed extract presents promising opportunities for further exploration and application. Future research can focus on evaluating the antimicrobial properties of the synthesized nanoparticles against a wide range of bacterial and fungal strains, which may lead to their incorporation in biomedical and healthcare products such as wound dressings and antimicrobial coatings. Additionally, their potential as nanocarriers in drug delivery systems could be investigated, given their biocompatibility and surface reactivity. In the field of environmental science, MgO nanoparticles may serve as effective catalysts for the degradation of pollutants in wastewater treatment. Moreover, comprehensive toxicological studies—both *in vitro* and *in vivo*—are essential to ensure their safety for clinical and environmental use. Lastly, optimization of synthesis parameters such as extract concentration, pH, temperature, and calcination conditions can help tailor the nanoparticles for specific applications, enhancing their efficiency and functional performance in various industrial and scientific domains.

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