مجلة كلية التربية الاساسية
كلية التربية الاساسية – الجامعة المستنصرية
Journal of the College of Basic Education Vol.31 (NO. 131) 2025, pp. 16-24

Green Synthesis and characterization of Magnesium oxide nanoparticles by using Garlic Extract

Farah Noori Ibraheem[1]*, Suzan Saadi Hussain[2], Haitham Talib Hussain [3]
[1] Department of Biology, College of Science, University of Mustansiriya, Baghdad, Iraq
[2]Department of Biology, College of Science, University of Mustansiriya, Baghdad, Iraq
[3] Department of Applied Physics, College of Applied Science, University of Technology, Baghdad, Iraq
[2]suzansaadialroznamachi@uomustansiriyah.edu.iq ,
[3]haithamT.hussein@uotechnology.edu.iq
Corresponding author E-mail: fofanoori99@uomustansiriyah.edu.iq

Abstract

This study presents the green synthesis of magnesium oxide nanoparticles (MgO NPs) using garlic (Allium sativum) extract as a natural reducing and capping agent, combined with sodium hydroxide (NaOH) for the precipitation process. The synthesized MgO NPs were characterized using advanced analytical techniques, including UV-Vis spectroscopy for optical properties, Fourier-transform infrared spectroscopy (FTIR) to confirm functional groups involved in the synthesis, X-ray diffraction (XRD) to assess crystallinity, and scanning electron microscopy (SEM) for morphological analysis. Results showed that these techniques confirmed the successful synthesis of MgO NPs and exhibited promising properties suitable for various applications, including antibacterial activities. This research highlights the potential of plant-based methods in advancing sustainable nanomaterial production. The green synthesis approach demonstrated advantages such as simplicity, cost-effectiveness, and reduced environmental impact

Keywords: Green Synthesis, Nanoparticle Characterization, Reactive Oxygen Species (ROS), Magnesium Oxide Nanoparticles (MgO NPs), Eco-Friendly Nanotechnology.

مجلة كلية التربية الاساسية
كلية التربية الاساسية – الجامعة المستنصرية
Journal of the College of Basic Education Vol.31 (NO. 131) 2025, pp. 16-24

Introduction

The rapid advancements in nanotechnology have revolutionized multiple fields, including medicine, agriculture, and environmental science[1]. Nanotechnology is one of the most promising scientific and technological fields of the 21st century, focusing on the design and development of materials at the nanoscale, typically below 100 nanometres. Nanomaterial's exhibit unique properties, such as enhanced surface area and high chemical reactivity, making them ideal for a wide range of applications in medicine, agriculture, energy, and environmental science [2] [3]. Among the various nanomaterial's, Magnesium oxide nanoparticles (MgO NPs) have attracted significant attention due to their remarkable physicochemical properties, such as high thermal stability, surface reactivity, and antimicrobial activity [4]. Traditionally, MgO NPs are synthesized through chemical and physical methods, which often involve toxic reagents, high energy consumption, and environmental risks. In recent years, green synthesis methods have emerged as a sustainable alternative for nanoparticle production, leveraging plant extracts for their rich content of bioactive compounds that act as natural reducing and stabilizing agents [5]. Garlic (Allium sativum), is a widely recognized medicinal plant, is known for its high content of sulfur-containing compounds, phenolics, and flavonoids, making it an excellent candidate for nanoparticle synthesis. Numerous studies have already demonstrated that Garlic may help prevent age-related illnesses, cardiovascular disease, and cancer [6] [7]. Certain organo sulfur compounds are referred to as having therapeutic and helpful qualities [8] .Garlic extract is a high source of flavonoids and phenolics, which are crucial for the reduction process used to create metal nanoparticles [9]. The growing interest in green nanotechnology has led to the development of environmentally friendly methods for synthesizing metal oxide nanoparticles, by emphasizing the use of environmentally friendly resources; this research contributes to the growing demand for sustainable and cost-effective nanotechnology solutions while exploring potential applications of MgO NPs, particularly in antibacterial and environmental domains. [10]

This study explores the preparation of MgO NPs using garlic extract and NaOH, with the synthesized nanoparticles characterized using multiple analytical techniques. UV-Vis spectroscopy was employed to monitor the formation of MgO NPs and study their optical properties. FTIR analysis identified the bioactive compounds from garlic extract that facilitated the reduction and stabilization processes. XRD analysis confirmed the crystalline structure of MgO, while SEM provided insights into the size and morphology of the nanoparticles.

Materials and Methods

2.1 Preparation of Garlic Extract for Magnesium Oxide NPs.

Wash the fresh garlic cloves thoroughly with distilled water to remove any impurities or contaminants. Peel the cloves and cut them into small pieces for extraction, then add a specific amount of hot distilled water to the crushed garlic. Subsequently, stir the mixture continuously and leave it to soak at room temperature for 24hrs. After that filtration the extract using filters paper to remove fibers and insoluble materials, kept at 4℃ for later use. [10]

2.2 Synthesis of MgO Nanoparticles.

Magnesium nitrate hexahydrate $Mg(NO_3)_2.6H_2O$ was used as the precursor for magnesium ions. In a beaker, 0.1 M was prepared by dissolving the required amount of $Mg(NO_3)_2.6H_2O$ in distilled water. Garlic extract (50 mL) was added dropwise to the solution under constant stirring at room temperature, add (0.2M) of Sodium hydroxide dropwise by the burette to ensure controlled addition to the reaction mixture until the pH reached 10, leading to the formation of a white precipitate, the mixture was stirred continuously at 70°C to complete the reaction. After the complete addition of sodium hydroxide, the mixture was covered with aluminum foil and heated for one hour. It is then allowed to cool down, during which the material precipitates. After that filtering the solution by using whattman No.1, the resulting precipitate was collected and washed three times with distilled water to remove impurities, the product was air-dried under ambient air conditions. Finally, the dried product was calcined at 500°C for 2 hours in a muffle furnace to convert it into crystalline MgO nanoparticles.[11]

2.3 Mechanism of MgO NPs formation using Garlic Extract.

Garlic contains various bioactive molecules such as phenolic compounds, flavonoids, sulfur compounds and allicin ($C_6H_{10}OS_2$), which act as reducing and stabilizing agents in the synthesis of MgO-NPs, these compounds provide functional groups (-OH and –C=O) that facilitate the formation of nanoparticles. When magnesium nitrate hexahydrate is added to the garlic extract under continuous stirring , the bioactive compounds reduce Mg^{2+} ions and induce the formation of magnesium hydroxide :

$$Mg^{2+} + 2OH^- \longrightarrow Mg(OH)_2 \downarrow$$

The $Mg(OH)_2$ precipitate is subjected to calcination 500℃, leading to dehydration and the formation of MgO NPs, water molecules (H_2O) are released, resulting in the crystallization of MgO NPs :

$$Mg(OH)_2 \longrightarrow MgO + H_2O\uparrow$$

2.4 Characterization of MgO NPs

UV-Vis Spectroscopy: The formation of MgO NPs was confirmed by measuring the absorbance in the range of 200–800 nm. Fourier-transform Infrared Spectroscopy (FTIR): FTIR analysis was conducted to identify the functional groups involved in the reduction and stabilization process. X-ray Diffraction (XRD): XRD was performed to determine the crystalline structure and phase purity of the synthesized MgO NPs. Scanning Electron Microscopy (SEM): SEM analysis was carried out to study the surface morphology and size distribution of the nanoparticle.[13]

3. Result and Desiccation

3.1 Characterization of MgO Nanoparticles

3.1.1 UV-Vis Spectroscopy:

The UV-Vis absorption spectrum of the synthesized MgO NPs exhibited a characteristic absorption peak at ~250 nm shown in Figuer.1, indicating the successful formation of magnesium oxide nanoparticles. This peak corresponds to the electronic transitions in Mg-O bonds NPs. The absorbance gradually decreases with increasing wavelength.[14]

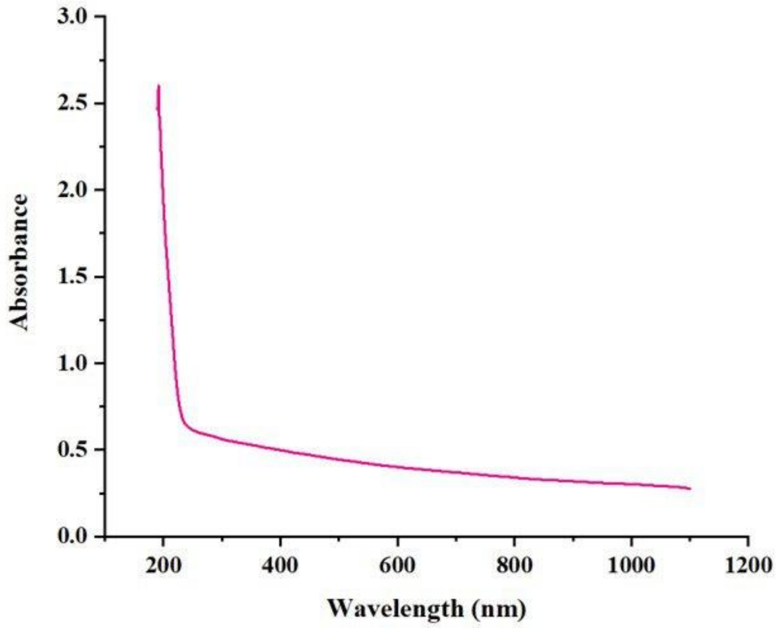

Figure 1: exhibited the absorbance of MgO NPs.

3.1.2 FTIR Analysis:

FTIR spectra revealed the presence of functional groups that facilitated the reduction and stabilization of MgO NPs, garlic contains various bioactive molecules such as phenolic compounds, flavonoids, sulfur compounds and allicin (C6H10OS2), which act as reducing and stabilizing agents in the synthesis of MgO-NPs, these compounds provide functional groups (-OH and –C=O) that facilitate the formation of nanoparticles. Peaks at ~3450 cm^{-1} and ~1630 cm^{-1} were attributed to O-H and C=O stretching vibrations, respectively, confirming the role of bioactive compounds in the synthesis process. While the peak at 864.1 cm^{-1} attributed to presences Mg-O bond that indicated to conformation of Magnesium oxide NPs, display in Figure 2. [15]

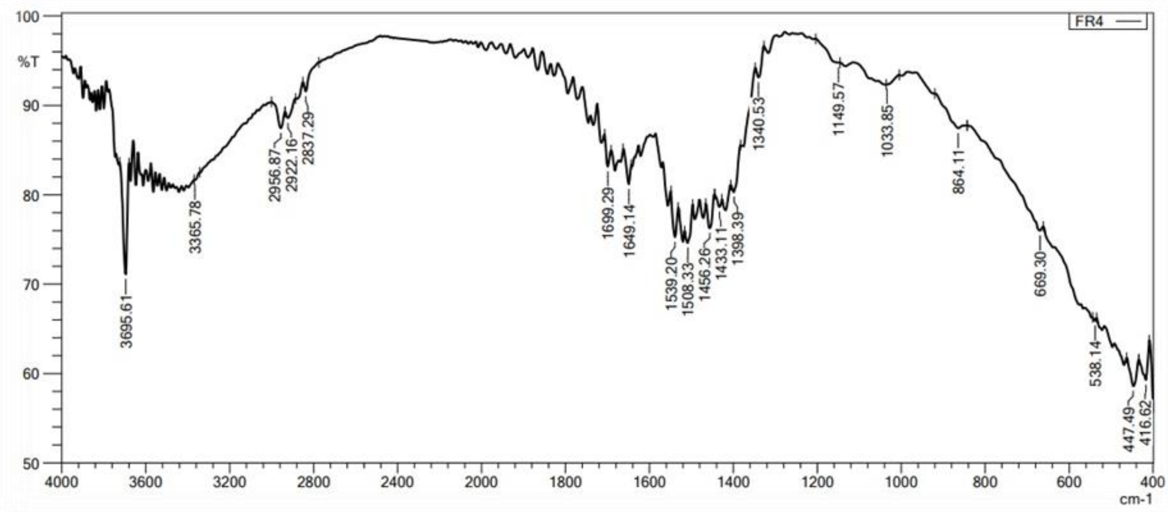

Figure 2: Shown the FTIR analysis of MgO NPs.

3.1.3 XRD Analysis:

X-ray diffraction patterns confirmed the crystalline nature of MgO NPs with sharp peaks corresponding to the cubic phase of MgO. The crystalline structure of MgO NPs was ascertained by X-ray diffraction. The x-ray patterns of magnesium oxide nanoparticles produced by green synthesis at 500 ℃ calcination temperatures are shown in Fig. 3, the diffraction patterns showed clear, intense peaks at 18.1 degrees, 32.7 degrees, 37.31 degrees, 51.11 degrees, 58.11 degrees, and 62.18 degrees, which corresponded to miller index (hkl) values of (100), (002), (101), (102), (110) and (002), respectively. Would be listed under the cubic structure that JCPDS card No. 96-900-6331 confirms. The Debye-Scherrer equation was used to determine the crystalline size of MgO NPs [16]:

$D = k\,\lambda/\beta \cos\theta$

where λ is the wavelength of Cu. $K\alpha$ radiation (0.154nm), β is the full width half maximum, θ is the diffraction angle, and ꟽk' is the shape factor equal to 0.94.According to this result, the peaks of the XRD patterns were somewhat changing as the calcinations increased. This was caused by stress in the crystals that was connected to the particle size. This enhanced the produced nanoparticles' crystal nature and great purity.

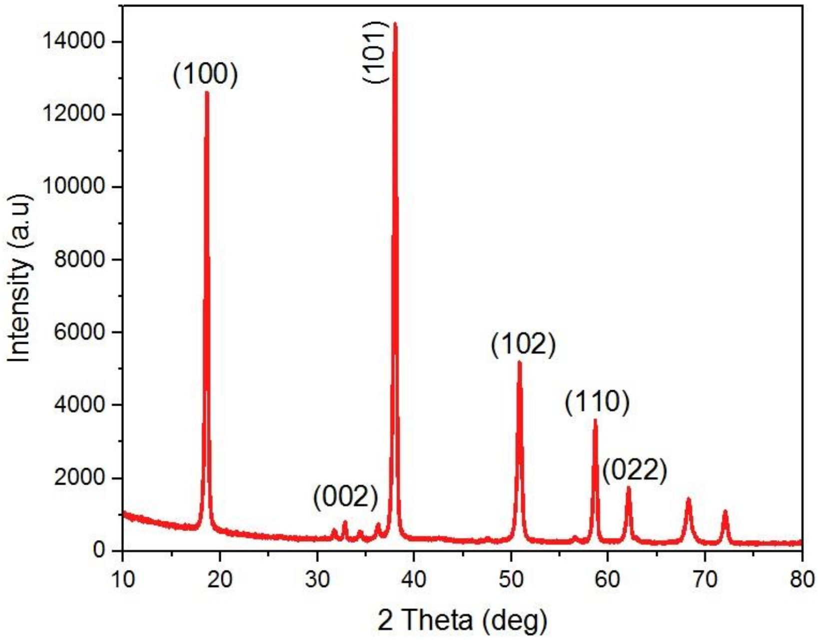

Figure 3: exhibited the X-ray diffraction of MgO NPs.

3.1.4 SEM Analysis:

SEM images revealed that the MgO NPs had a spherical morphology with a size range of 70–80 nm. Some agglomeration was observed due to the clustering of nanoparticles could result from electrostatic interactions, van der Waals forces or high surface energy of the nanoparticles and high calcination temperature. [17]

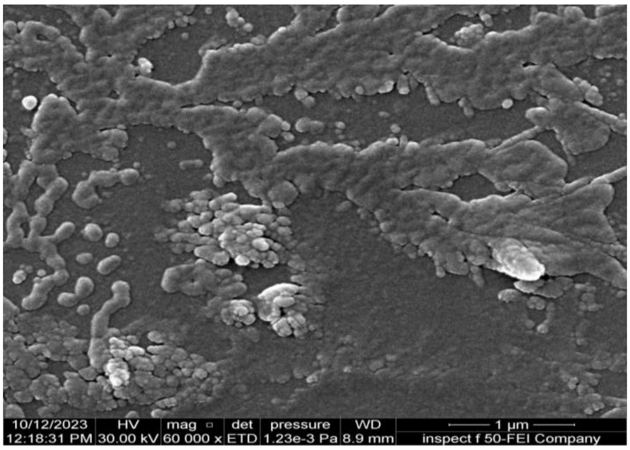

Figure 4: display the SEM analysis of MgO NPs.

Conclusion

This study successfully demonstrated the green synthesis of magnesium oxide nanoparticles (MgO NPs) using garlic extract and sodium hydroxide. The synthesized MgO NPs exhibited desirable characteristics, including a crystalline structure confirmation by XRD, nanoscale size ranging in 70-80 nm indicating by FE-SEM, while at UV-analysis the absorbance gradually decreases with increasing wavelength. And significant may be used as antibacterial activity. The use of garlic extract as a natural reducing and stabilizing agent highlights the potential of plant-based methods for sustainable nanoparticle synthesis. The results suggest that MgO NPs synthesized via this green method have potential applications in various fields, including antimicrobial treatments, environmental remediation, and biomedicine.

Acknowledgements

Authors would like to thank Mustansiriyah University (www.Mustansiriyah.com) for the encouragement and providing excellent facilities for the above work.

References:

[1] Malik, S., Muhammad, K., & Waheed, Y. (2023). Nanotechnology: A revolution in modern industry. *Molecules*, *28*(2), 661.

[2] Ashraf, S. A., Siddiqui, A. J., Abd Elmoneim, O. E., Khan, M. I., Patel, M., Alreshidi, M., ... & Adnan, M. (2021). Innovations in nanoscience for the sustainable development of food and agriculture with implications on health and environment. *Science of the Total Environment*, *768*, 144990.

[3] Kheiriabad, S., Jafari, A., Namvar Aghdash, S., Ezzati Nazhad Dolatabadi, J., Andishmand, H., & Jafari, S. M. (2024). Applications of advanced nanomaterials in biomedicine, pharmaceuticals, agriculture, and food industry. *BioNanoScience*, 1-24.

[4] Parveen, S., Bhat, M. Y., Wani, A. H., Shah, M. A., Devi, H. S., & Koka, J. A. (2021). A Benign Route for the Synthesis of MgO Nanoparticles and Their Antifungal Activity. Nano Trends: A Journal of Nanotechnology and Its Applications. 2021; 23 (3): 37–44p. A Benign Route for the Synthesis of MgO Nanoparticles and Their Antifungal Activity Parveen et al. STM Journals, 2

[5] Prasanth, R., Kumar, S. D., Jayalakshmi, A., Singaravelu, G., Govindaraju, K., & Kumar, V. G. (2019). Green synthesis of magnesium oxide nanoparticles and their antibacterial activity.

[6] Rahman, K. (2003). Garlic and aging: new insights into an old remedy. *Ageing research reviews*, *2*(1), 39-56.

[7] Das, D., Mitra, A., Zaky, M. Y., Pathak, S., & Banerjee, A. (2024). A Review on the Efficacy of Plant-derived Bio-active Compounds Curcumin and Aged Garlic Extract in Modulating Cancer and Age-related Diseases. *Current Reviews in Clinical and Experimental Pharmacology Formerly Current Clinical Pharmacology*, *19*(2), 146-162.

[8] Borek, C. (2001). Antioxidant health effects of aged garlic extract. *The Journal of nutrition*, *131*(3), 1010S-1015S.

[9] El-Refai, A. A., Ghoniem, G. A., El-Khateeb, A. Y., & Hassaan, M. M. (2018). Eco-friendly synthesis of metal nanoparticles using ginger and garlic extracts as biocompatible novel antioxidant and antimicrobial agents. *Journal of Nanostructure in Chemistry*, *8*, 71-81.

[10] Ahamed, M., Akhtar, M. J., & Khan, M. M. (2023). Green-fabricated MgO nanoparticles: a potent antimicrobial and anticancer agent. *Journal of King Saud University-Science*, *35*(8), 102889.

[11] Von White, G., Kerscher, P., Brown, R. M., Morella, J. D., McAllister, W., Dean, D., & Kitchens, C. L. (2012). Green synthesis of robust, biocompatible silver nanoparticles using garlic extract. *Journal of nanomaterials*, *2012*(1), 730746.
[12] Abid, M. A., Abid, D. A., Aziz, W. J., & Rashid, T. M. (2021). Iron oxide nanoparticles synthesized using garlic and onion peel extracts rapidly degrade methylene blue dye. *Physica B: Condensed Matter*, *622*, 413277.
[13]Parveen, S., Bhat, M. Y., Wani, A. H., Shah, M. A., Devi, H. S., & Koka, J. A. (2021). A Benign Route for the Synthesis of MgO Nanoparticles and Their Antifungal Activity. Nano Trends: A Journal of Nanotechnology and Its Applications. 2021; 23 (3): 37–44p. A Benign Route for the Synthesis of MgO Nanoparticles and Their Antifungal Activity Parveen et al. STM Journals, 2
[14] Abd Ali, Z. D., Ahamed, A. A., Dakhil, O. A. A., & Albeer, A. (2023). Optical and Electrical Properties of Nano Magnesium Oxide Doped with Polyvinylpyrrolidone (PVP) Thin Films. Al-Mustansiriyah Journal of Science, 34(4), 129-137.
[15] Palanisamy, G., & Pazhanivel, T. (2017). Green synthesis of MgO nanoparticles for antibacterial activity. Int Res J Eng Technol, 4(9), 137-141.
[16] Sooväli, L., Rõõm, E. I., Kütt, A., Kaljurand, I., & Leito, I. (2006). Uncertainty sources in UV-Vis spectrophotometric measurement. Accreditation and quality assurance, 11, 246-255.
[17] Rotti, R. B., Sunitha, D. V., Manjunath, R., Roy, A., Mayegowda, S. B., Gnanaprakash, A. P., ... & Khidir, E. B. (2023). Green synthesis of MgO nanoparticles and its antibacterial properties. Frontiers in chemistry, 11, 1143614.