INFLUENCE OF PLANT LEAF EXTRACTS ON THE STRUCTURAL AND BIOLOGICAL PROPERTIES OF SYNTHESIZED MAGNESIUM OXIDE NANOPARTICLES

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Abstract

This research investigates the impact of different leaf extracts on the characteristics (such as morphology, size, and crystallinity) and biological activities (including antidiabetic, antioxidant, anti-inflammatory, and antacid effects) of magnesium oxide nanoparticles. The green synthesis of MgO NPs was performed using aqueous leaf extracts from *Oroxylum indicum* and *Moringa oleifera* as eco-friendly stabilizing agents. The synthesized MgO NPs underwent characterization through various techniques, including X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), UV-visible spectroscopy (UV-Vis), scanning electron microscopy with energy-dispersive X-ray analysis (SEM-EDX), and thermogravimetric analysis (TG-DTA) to assess their structural, morphological, and thermal properties. Biological studies assessed antioxidant activity using the DPPH radical scavenging method, while anti-inflammatory, anti-diabetic, and acid-neutralizing activities were evaluated through egg albumin denaturation, α-amylase inhibition, and back titration methods, respectively. Results showed that both *Oroxylum indicum* and *Moringa oleifera* extracts produced MgO NPs with excellent structural and biological properties, but significant differences were noted between the two. This study highlights the critical role that the choice of plant extracts plays in green synthesis, significantly impacting the structural and biological properties of the nanoparticles.

Keywords: MgO NPs, *Oroxylum indicum* and *Moringa oleifera*, green synthesis, structural and biological properties

Introduction

Nanotechnology has emerged as a transformative field in modern science, leveraging materials at the nanoscale to develop innovative solutions across various domains, including medicine, electronics, and environmental science. Among the various nanomaterials, magnesium oxide nanoparticles (MgO NPs) have garnered significant attention due to their unique structural, optical, and biological properties. These nanoparticles are known for their antibacterial, antifungal, and antioxidant activities, making them promising candidates for biomedical applications (Karthikeyan *et al.*, 2020). The traditional methods of synthesizing MgO NPs often involve chemical reagents that may pose environmental and health risks. In contrast, green synthesis offers a more sustainable approach, utilizing plant extracts as reducing and stabilizing agents. This method not only minimizes toxic by-products but also harnesses the natural properties of phytochemicals present in plant materials (Parveen *et al.*, 2019). Two plants that have shown potential for this purpose are *Oroxylum indicum* and *Moringa oleifera*, both renowned for their medicinal properties and rich phytochemical compositions. *Oroxylum indicum*, commonly known as the trumpet tree, is noted for its diverse therapeutic applications, including anti-inflammatory and antimicrobial effects (Singh *et al.*, 2017). Meanwhile, *Moringa oleifera*, often referred to as the "drumstick tree," is celebrated for its nutritional and medicinal benefits, with various studies highlighting its antioxidant and antibacterial activities. This research aims to compare the structural and biological properties of MgO NPs synthesized via

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green methods using leaf extracts of *Oroxylum indicum* and *Moringa oleifera*. By analyzing the differences in nanoparticle characteristics, including size, morphology, and biological efficacy, this study seeks to elucidate the potential of these plant extracts in enhancing the green synthesis of MgO NPs. These insights could lead to the creation of eco-friendly nanomaterials with improved structural and functional properties.

Materials and Methods

Materials

The leaves of *Oroxylum indicum* and *Moringa oleifera* used in this study were sourced from naturally growing plants. Commercial magnesium sulphate heptahydrate (Epsom salt) served as the precursor for the synthesis. The freshly collected leaves were cleaned, air-dried for 2–3 weeks, ground into a fine powder, and stored in air-tight container. For the synthesis process, 5 g of the dried powder from each plant were weighed and mixed separately with 100 mL of distilled water. These mixtures were heated to 60 °C for 30 minutes while stirring to ensure uniformity. Once heated, the solutions were cooled and filtered through Whatman No. 1 filter paper, with the resulting filtrates collected separately. These filtrates were subsequently utilized for the synthesis of magnesium oxide nanoparticles.

(i) (ii)

Figure 1. Photographs of (i) Moringa oleifera and (ii) Oroxylum indicum leaves

Preparation of magnesium oxide nanoparticles via different leaf extracts

Magnesium oxide nanoparticles were synthesized using aqueous extracts from *Oroxylum indicum* and *Moringa oleifera* leaf powders. During the process, 100 mL of the leaf extract solutions were gradually added dropwise to a 0.2 M solution of $MgSO_4 \cdot 7H_2O$ (200 mL) while stirring at 600 rpm. After thorough mixing, 2 M NaOH was introduced dropwise to bring the pH to around 10, and the mixtures were maintained at 90°C for 3 hours. These precipitates were separated via centrifugation at 7500 rpm for 20 minutes at room temperature, then washed three times with distilled water and once with ethanol. The precipitates were dried to remove any remaining moisture and ethanol, ground into powder using a mortar and pestle, and then calcined at temperatures of 600 °C for *both plant leaf* extracts, each for 5 hours.

Characterization

The formation of green-synthesized MgO nanoparticles was confirmed using a UV-visible spectrophotometer (UV-1800, Shimadzu). Their diffraction patterns, crystalline structure, and purity were analyzed with an X-ray diffractometer (MultiFlex 2kW, Rigaku, D/max 2200, Japan; D8 Advance X-ray Diffractometer, Bruker, Jermany). The morphology and elemental composition of the MgO nanoparticles were examined through scanning electron microscopy

(SEM) coupled with energy-dispersive X-ray analysis (SEM-EDX) (JSM-6701F/JED 2300, JEOL, Japan). A Fourier transform infrared (FT IR) spectrometer (PerkinElmer, Spectrum Two) was used to identify the functional groups present in the MgO nanoparticles. Raman spectroscopy (PerkinElmer) was employed for crystallinity and phase identification, complementing the XRD findings. Finally, the thermal stability of the MgO nanoparticles was assessed using a TG-DTA thermal analyzer (DTG-60H, SHIMADZU, Japan).

Determination of antioxidant activity

The antioxidant activity of the synthesized MgO nanoparticles has been evaluated using the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging assay, a widely used method to assess antioxidant properties by measuring a substance's ability to neutralize free radicals with a UV-visible spectrophotometer. A sample solution was prepared by mixing 1.5 mL of 20 µM DPPH solution with 1.5 mL of MgO nanoparticle solution (ranging from 125 to 1.95 µg/mL) in a methanol and DMSO mixture. The solution was vigorously mixed and kept in the dark for 30 minutes before measuring its absorbance at 517 nm against a blank. Control absorbance was measured without the test samples, and the radical scavenging activity was calculated using the expressed formula:

$$\% \text{ RSA} = \frac{A_{\text{Control}} - (A_{\text{Sample}} - A_{\text{Blank}})}{A_{\text{Control}}} \times 100$$

Determination of anti-inflammatory activity

The inhibitory activity of the test samples on egg albumin denaturation was utilized to investigate the potential mechanisms behind the anti-inflammatory effects of MgO nanoparticles using UV-visible spectrophotometry (Naveed ***et al.,*** **2022**). This method measures the ability of a compound to inhibit protein denaturation, an indicator of anti-inflammatory potential, as protein denaturation is a process linked to inflammatory conditions. To prepare the sample solution, 400 µL of the test sample was mixed with 300 µL of egg albumin solution in separate test tubes. The reaction mixture's pH was adjusted to 6.4 with sodium phosphate buffer (2.9 mL). To induce denaturation of the egg albumin, the mixture was incubated at room temperature for 20 minutes and then heated in a water bath at 65–70 °C for 15 minutes. After cooling, the absorbance was measured at 660 nm, using a solution without test samples as the control and the radical scavenging activity was calculated using the expressed formula:

$$\% \text{ inhibition} = \frac{A_{\text{Control}} - A_{\text{Sample}}}{A_{\text{Control}}} \times 100$$

Determination of antidiabetic activity

The anti-diabetic activity of MgO nanoparticles was evaluated through an α-amylase inhibition assay, a standard assay for assessing the potential of compounds to reduce carbohydrate breakdown, which can help manage blood glucose levels, using a UV-visible spectrophotometer with slightly modified to previous studies. In separate test tubes, 1 mL of the sample solution and 1 mL of α-amylase solution were mixed to prepare different concentrations (ranging from 125 to 1.95 µg/mL). The reaction mixture was adjusted to pH 6.9 with 1 mL of sodium phosphate buffer and incubated at room temperature for 10 minutes to enhance α-amylase inhibitory activity. Afterward, 400 µL of 1% starch solution was added, followed by

another 10-minute incubation at room temperature. Next, 500 µL of DNSA reagent was added, and the mixture was heated in a water bath at 85–90°C for 10 minutes. Once cooled, the absorbance was measured at 540 nm. A control reading without test samples was also taken for comparison and the radical scavenging activity was calculated using the expressed formula:

$$\% \text{ inhibition} = \frac{A_{Control} - A_{Sample}}{A_{Control}} \times 100$$

Determination of acid neutralizing activity

The acid-neutralizing activity of magnesium oxide nanoparticles synthesized from *Moringa oleifera* and *Oroxylum indicum* leaf extracts was assessed using a back titration method. In the procedure, 20 mL of standardized hydrochloric acid (HCl) was added to a 250 mL Erlenmeyer flask, followed by 1 mL of the MgO NP sample solution. After mixing, three drops of phenolphthalein indicator were added, and the mixture was titrated with standardized sodium hydroxide (NaOH) until a pink color appeared. This titration was repeated three times, and the average titre volume of NaOH needed to neutralize the excess HCl was recorded. The experiment was conducted for various concentrations of MgO NPs and compared with a standard antacid drug, Siloxogene. The moles of excess HCl neutralized by each sample were calculated and expressed in milliequivalents (mEq). The acid-neutralizing capacity (ANC) was then computed using a specific formula, along with the ANC per dose of the test substances (Ramadan and Turk, 2023).

$$\text{ANC (mEq)} = (V_{HCl} \times N_{HCl}) - (V_{NaOH} \times N_{NaOH}) \quad \ldots\ldots. (1)$$

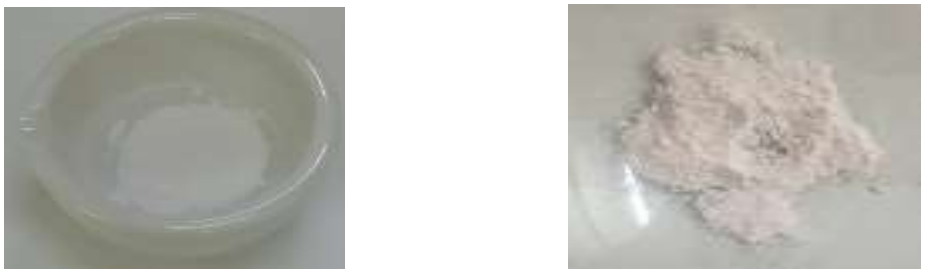
$$\text{ANC (mEq/g)} = \frac{\text{ANC (mEq)}}{\text{dose of test sample}} \quad \ldots\ldots. (2)$$

Where, mEq represents the milliequivalents of acid consumed; N_{HCl} is the normality of HCl; N_{NaOH} is the normality of NaOH;V_{HCl} is the volume of HCl used; V_{NaOH} is the volume of NaOH used.

Results and Discussion

Green synthesis of magnesium oxide nanoparticles

Magnesium oxide nanoparticles (MgO NPs) were synthesized from commercial Epsom salt ($MgSO_4 \cdot 7H_2O$) using phytochemicals present in *Oroxylum indicum* and *Moringa oleifera* leaf extracts as reducing and stabilizing agents. The resulting MgO NPs appeared white, powdery, crystalline, and insoluble in water, as confirmed by characterization techniques (Figure 2).



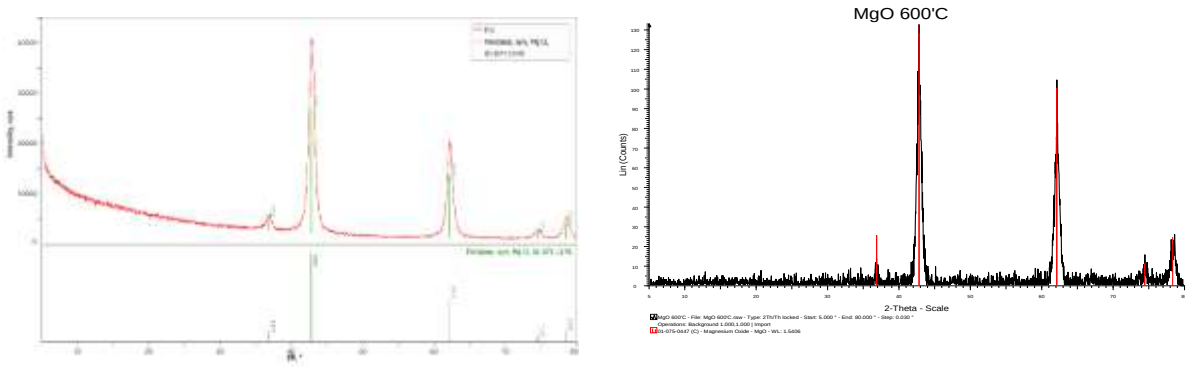
(i) (ii)

Figure 2. Magnesium oxide nanoparticles synthesized from aqueous leaf extracts of (i) Moringa oleifera and (ii) Oroxylum indicum

Characteristic analysis of synthesized MgO NPs

X-ray diffraction analysis

X-ray diffraction (XRD) analysis was employed to assess the crystalline structure and phase purity of magnesium oxide nanoparticles synthesized from *Moringa oleifera* and *Oroxylum indicum* leaf extracts (Figure 3). Both *Moringa oleifera* and *Oroxylum indicum* derived MgO NPs exhibited XRD peaks corresponding to the typical crystal planes 111, 200, 222, 311, and 222 of the MgO cubic rock-salt structure (JCPDS = 071-1176 and 01-075-0447). Lattice parameters for MgO NPs synthesized using *Moringa oleifera* extract are (a = b = c = 4.217 Å), while for MgO NPs synthesized using *Oroxylum indicum* extract, they are slightly shorter at (a = b = c = 4.213 Å). This minor variation in lattice parameters may be due to differences in organic stabilization layers imparted by each plant extract. Both lattice systems have axial angles of $\alpha = \beta = \gamma = 90°$, confirming a cubic crystal structure. MgO NPs synthesized using *Moringa oleifera* extract have a smaller crystallite size, averaging 10.39 nm, while MgO NPs synthesized using *Oroxylum indicum* extract have a larger average crystallite size of 14.03 nm. A smaller crystallite size increases surface energy, which leads to a higher surface area. This difference in crystallite sizes may influence properties like reactivity and stability, particularly beneficial in applications requiring high surface interaction, such as catalysis, coatings and sensors. While both extracts successfully produce MgO with a cubic structure, differences in crystallite sizes and lattice parameters demonstrated the different effects of each plant source on the nano structure.



(i) **(ii)**

Figure 3. XRD patterns of MgO NPs using aqueous leaf extracts of (i) *Moringa oleifera* and (ii) *Oroxylum indicum* at 600 °C

SEM-EDX analysis

Scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDX) were used to analyze magnesium oxide nanoparticles synthesized from *Moringa oleifera* and *Oroxylum indicum* leaf extracts, focusing on their morphology and elemental composition. SEM analysis revealed that MgO NPs synthesized using both plant leaf extracts–were primarily spherical and uniform (Figures 4 and 5). The nanoparticles exhibited some degree of agglomeration due to magnetic and van der Waals interactions, which may slightly reduce their surface area. However, this aggregation is unlikely to significantly affect their activity in certain applications.

The elemental mass ratio for *Moringa oleifera* based MgO NPs was found to be Mg = 47.65% and O = 50.43%, yielding an approximate Mg: O = 1:1, which closely matches the

stoichiometric composition expected for MgO. In its ideal stoichiometric condition, MgO NPs have a perfect face-centered cubic (FCC) structure with each magnesium ion being surrounded by six oxygen ions. This configuration results in a highly symmetric, well-ordered crystal lattice with an optimal lattice constant. In this configuration, the lattice parameter remains stable due to the highly symmetric and well-ordered crystal structure, with no significant lattice distortions. This ratio suggests a high purity level of MgO formation with minimal interference from impurities. The carbon content was measured at 1.92%, likely from the organic compounds present in the *Moringa oleifera* leaf extract, which may remain on the nanoparticle surface as a thin layer, potentially stabilizing the particles and contributing to their uniform morphology.

For MgO NPs synthesized using *Oroxylum indicum* extract, the elemental mass ratio was found to be Mg = 63.01% and O = 30.07%, resulting in an approximate Mg:O ratio of 2:1. This deviation from the standard 1:1 Mg:O ratio could be due to variations in synthesis conditions or differences in the binding and reduction capabilities of the Oroxylum indicum extract. The presence of non-stoichiometric conditions may influence Mg-O-Mg bonding, leading to deviations in the crystal structure. This indicates an excess of magnesium in the crystal lattice, as some magnesium ions may occupy interstitial sites or create clusters rather than participating in the ideal cubic lattice structure. This can result in a deviation from a purely cubic structure, as excess magnesium atoms may occupy interstitial sites or form clusters, leading to local structural variations. Despite the non-stoichiometric conditions, the overall structure can still be categorized as cubic. The higher carbon content of 6.92% may be attributed to residual organic compounds in *Oroxylum indicum* leaf extract that were not fully decomposed, potentially forming a carbonaceous layer on the nanoparticle surface (Sharma and Kumar 2020; Gupta and Sharmar, 2022).

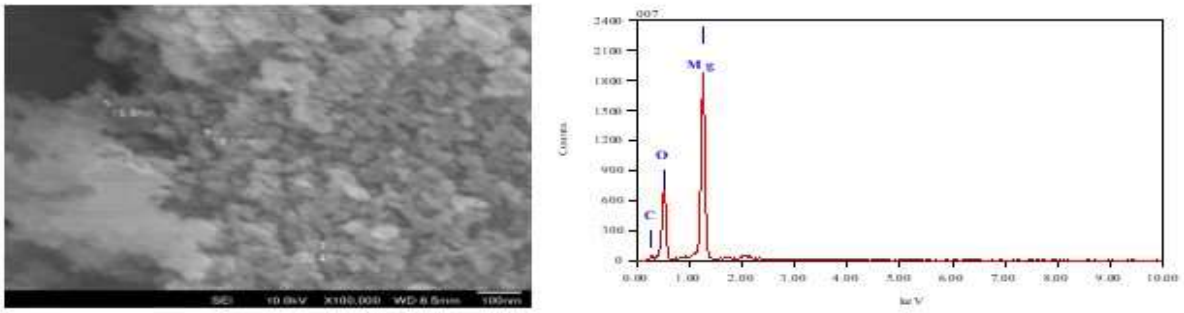


Figure 4. SEM-EDX image of MgO NPs using aqueous leaf extract of *Moringa oleifera*

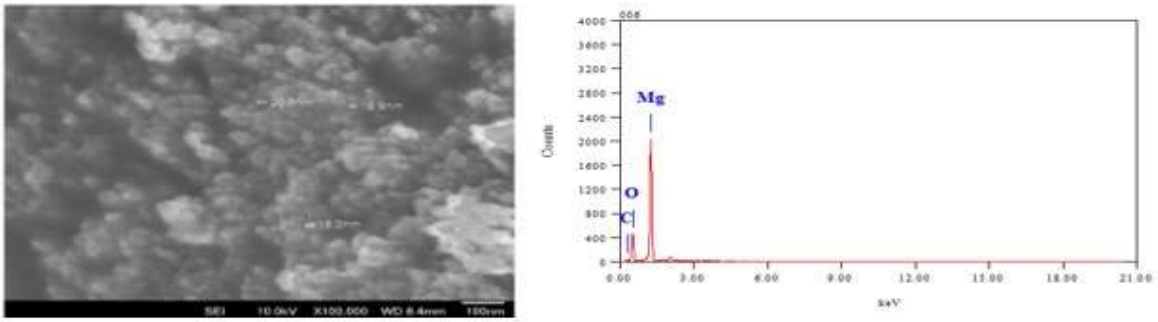
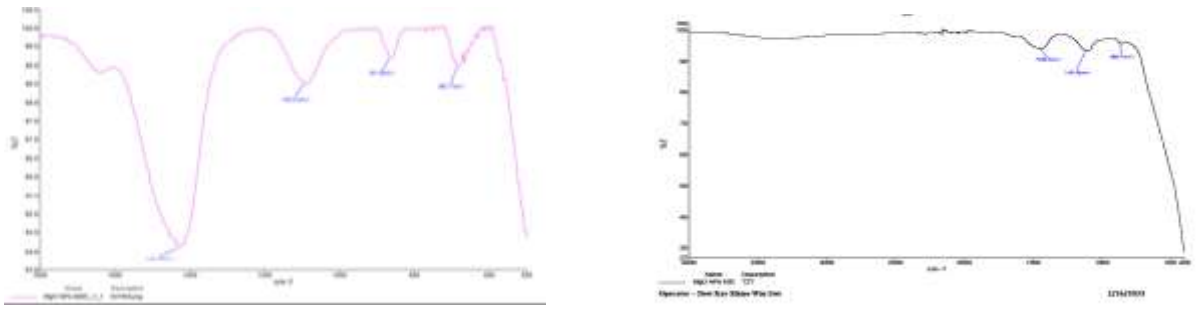


Figure 5. SEM-EDX image of MgO NPs using aqueous leaf extract of *Oroxylum indicum*

FT IR spectroscopic analysis

Fourier Transform Infrared (FT-IR) spectroscopy analysis of magnesium oxide nanoparticles synthesized from *Moringa oleifera* and *Oroxylum indicum* leaf extracts revealed the presence of various functional groups and chemical bonds on their surfaces, indicating successful capping and stabilization by phytochemicals from the extracts. For MgO NPs synthesized using *Moringa oleifera* extract, peaks at 1437, 1090, 861, and 683 cm^{-1} indicated the presence of organic compounds, which may act as stabilizing agents, influencing size and morphology (Figure 6a). The peaks at 861 and 683 cm^{-1} correspond to Mg-O vibrations, confirming the formation of MgO nanoparticles. The peak at 1437 cm^{-1} is associated with C–H bending vibrations, indicating the presence of organic compounds from the *Moringa oleifera* leaf extract which may contribute to nanoparticle stabilization. The peak at 1090 cm^{-1} correspond to C-O stretching, indicating the presence of phytochemicals from the plant extract on the MgO surface which may enhance stability and surface reactivity. In contrast, the FTIR spectrum for MgO NPs synthesized using *Oroxylum indicum* extract showed the peaks at 1439, 1107 and 860 cm^{-1} (Figure 6b). The peak at 1439 and 1107 cm^{-1}, similar to those observed in *Moringa oleifera*, correspond to C–H bending and C-O stretching vibrations. This indicates the presence of organic compounds from the *Oroxylum indicum* extract, which may contribute to the stabilization of MgO NPs. The peak at 846 cm^{-1} correspond to Mg-O bond vibrations, confirming the formation of MgO nanoparticles. The more complex FT IR pattern observed in *Moringa oleifera* based MgO NPs suggests a thicker organic layer, which may influence surface interactions and enhance nanoparticle reactivity (Verma and Soni, 2021; Patel and Mehta, 2022).



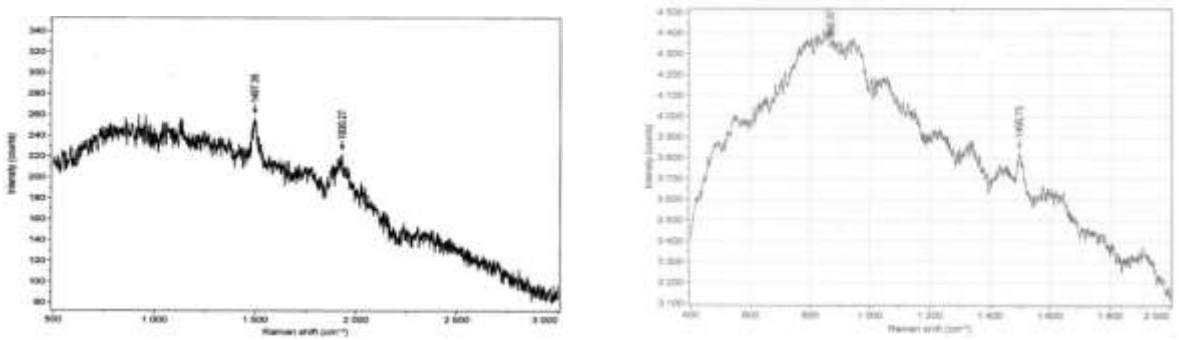
(a) (b)

Figure 6. FT IR spectra of MgO NPs using aqueous leaf extracts of (a) *Moringa oleifera* and (b) *Oroxylum indicum*

Raman spectroscopic analysis

Raman spectroscopy is a powerful analytical technique used to study molecular vibrations, crystal structures, and material properties. The Raman analysis of MgO nanoparticles synthesized using *Moringa oleifera* and *Oroxylum indicum* leaf extracts revealed the distinct vibrational modes that reflect the surface chemistry and stability of the NPs. MgO nanoparticles exhibit a Raman active vibrational mode with major Raman bands of 447 $cm^{-1,}$ 850 cm^{-1}, 1084 cm^{-1},1495 cm^{-1}, 1923 cm^{-1}, and 2322 cm^{-1} (Meenakshi *et al.*, 2012). For MgO NPs synthesized using *Moringa oleifera* extract, Raman peaks at 1497 and 1930 cm^{-1} correspond to C=C stretching of aromatic compounds or unsaturated bonds and C-H bending vibrations, suggesting interactions between the MgO matrix and organic residues from the *Moringa oleifera* extract,

which could stabilize the particles. MgO NPs synthesized using *Oroxylum indicum* extract show modes at 866 and 1495 cm^{-1}. The 866 cm^{-1} peak is typically associated with ~~of~~ vibrational mode of metal oxides. This peak may reflect lattice vibrations specific to MgO. The 1495 cm^{-1} peak closely matches that observed in *Moringa oleifera* based NPs, suggesting the presence of aromatic compounds in both plant extracts, which likely contribute to the stabilization of the MgO NPs. Variations in peak frequencies between the two extracts indicate that each plant's phytochemicals create different surface environments on the MgO NPs, possibly indicating the presence of varied stabilization mechanisms or interactions between ~~the~~ MgO and the bioactive compounds in these plant extracts (Bhatnagar *et al.,* 2021; Kumar *et al.,* 2018).

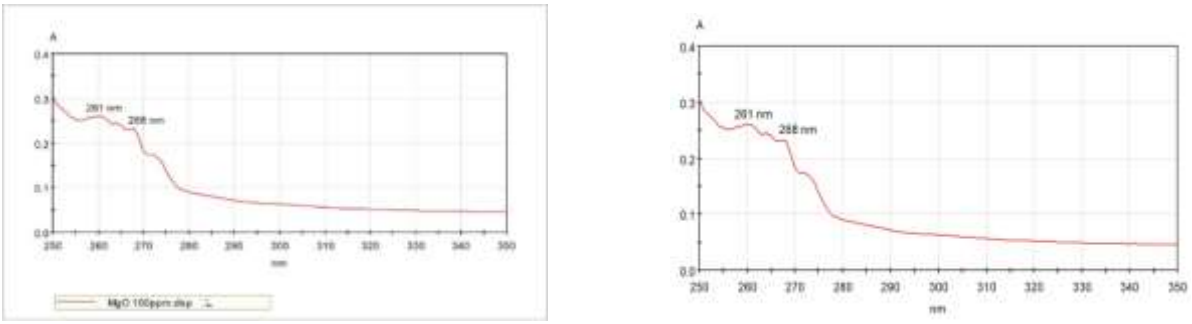


(a) (b)

Figure 7. Raman spectr*a* of MgO NPs using aqueous leaf extracts of (a) *Moringa oleifera* and (b) *Oroxylum indicum*

UV-visible spectroscopic analysis

Generally, green-synthesized MgO-NPs exhibit UV-visible absorption peaks typically ranging from 217 nm to 328 nm **(**Proniewicz *et al.,* 2024; Saidi *et al.,* 2023). Variations within this range are primarily due to differences in synthesis methods, particle sizes, and the nature of the biological reducing agents used. The UV-visible spectra of magnesium oxide nanoparticles synthesized using *Moringa oleifera* and *Oroxylum indicum* leaf extracts display a maximum absorption peak at 261 nm (Figure 8a and 8b). This characteristic peak is consistent with the typical UV absorption of MgO nanoparticles, indicating the successful synthesis and stability of these particles. The fact that both MgO NPs using *M. oleifera* and *O. indicum* leaf extracts show the same absorption peak suggests that the plant extracts did not significantly alter the electronic properties of the MgO core. This consistency implies that while the extracts act as capping agents, they do not alter the intrinsic optical characteristics of the MgO, making these NPs potentially suitable for various applications in catalysis and biomedicine. The plant-derived organic compounds likely surround the NPs but do not interfere with the MgO crystal structure, maintaining the characteristic UV absorption (Rao and Gupta, 2022).

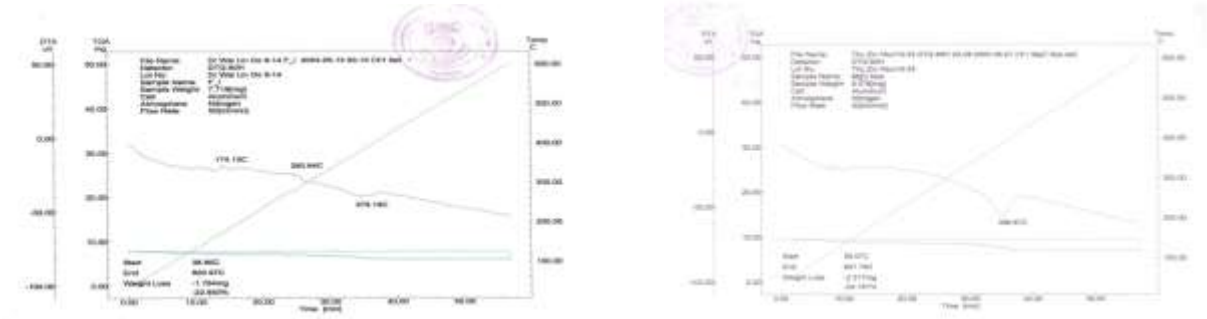


(a) (b)

Figure 8. UV-visible spectra of MgO NPs using aqueous leaf extracts of (a) *Moringa oleifera* and (b) *Oroxylum indicum*

TG-DTA thermographic analysis

Thermogravimetric analysis (TG) and differential thermal analysis (DTA) was employed to assess the thermal stability, decomposition behavior, and phase changes of MgO NPs synthesized from *Moringa oleifera* and *Oroxylum indicum* leaf extracts. In both thermographs of MgO NPs of two extracts, the TG curve indicates a 22.853% and 24.119% weight loss from 38.90°C to 600.97°C, attributed to moisture evaporation, volatile organic compounds, precursor decomposition. For MgO NPs synthesized using *Moringa oleifera* extract, DTA showed exothermic peaks at 174 °C and 280 °C, indicating energy release during the oxidation or decomposition of organic materials associated with the NPs. This dual peak pattern reflects the multi-step decomposition of lighter and heavier organic compounds in *Moringa oleifera.* The endothermic peak at 379.19 °C and 386.67°C for MgO NPs of both extracts confirmed the breakdown of organic stabilizers, leading to thermally stable crystalline MgO formation after 400 °C**.** Studies have shown that biosynthesized MgO nanoparticles exhibit high thermal stability, and their decomposition behavior depends on the nature of the stabilizing agents used during synthesis (Shanmugavel *et al.*, 2020; Yadav *et al.*, 2019, Kaviya *et al.*, 2011; Singh *et al.*, 2013).



(a) (b)

Figure 9. TG-DTA thermograph*s* of MgO NPs using aqueous leaf extracts of (a) *Moringa oleifera* and (b) *Oroxylum indicum*

In vitro assessment of the biological properties of synthesized MgO NPs via *Moringa oleifera* and *Oroxylum indicum* leaf extracts

The unique phytochemicals in various plant extracts, including phenolics, flavonoids, alkaloids, terpenoids, and proteins, play a crucial role in the reduction, growth, and stabilization of green-synthesized nanoparticles. These bioactive compounds act as natural reducing, stabilizing, and capping agents, affecting the NPs' size, shape, surface charge, and stability, which in turn determine their biological activities. This study investigated the antioxidant, antidiabetic, anti-inflammatory, and acid-neutralizing properties of MgO NPs synthesized with *Moringa oleifera* and *Oroxylum indicum* leaf extracts. Antioxidant, antidiabetic, and anti-inflammatory activities are measured by IC_{50} values (lower IC_{50} indicates higher activity), while acid neutralizing activity is measured in mEq/g.

Antioxidant activity

The IC_{50} of ascorbic acid in this assay was 1.90 μg/mL, which is notably higher than the MgO NPs synthesized with either *Moringa oleifera* (1.21 μg/mL) or *Oroxylum indicum* (1.16 μg/mL), representing in Table 1. This finding indicates that both green-synthesized MgO NPs exhibit superior antioxidant activity compared to standard ascorbic acid. This superior effectiveness is probably due to the combined action of MgO NPs with plant-derived antioxidant compounds, enhancing ROS-scavenging activity more than pure ascorbic acid. MgO NPs synthesized with *Oroxylum indicum* leaf extract exhibited the strongest antioxidant activity, with an IC_{50} of 1.16 μg/mL, likely due to the high phenolic and flavonoid content known for their ROS-scavenging properties. The MgO NPs synthesized with *Moringa oleifera* leaf extract show slightly lower antioxidant activity, which may be due to lower concentrations or less potent radical-scavenging bioactive compounds in the extract.

Antidiabetic activity

The IC_{50} of the standard antidiabetic drug metformin was 3.79 μg/mL, indicating that it is a more potent α-amylase inhibitor than MgO NPs synthesized with *Moringa oleifera* (5.54 μg/mL) and *Oroxylum indicum* (4.78 μg/mL), representing in Table 2. The slightly lower inhibition of the MgO NPs from *Moringa oleifera* compared to those synthesized with ~~from~~ *Oroxylum indicum* may be attributed to differences in phytochemical ~~content~~ composition and the potency of specific compounds. Despite this, both types of MgO NPs exhibit notable antidiabetic activity, with inhibition levels approaching that of metformin. This suggests that these green-synthesized MgO NPs may serve as natural alternatives for antidiabetic therapy, particularly when used in conjunction with other treatments.

Anti-inflammatory activity

The IC_{50} value for diclofenac sodium, a standard anti-inflammatory drug, was 6.77 μg/mL, which is higher than the values for MgO NPs synthesized from *Moringa oleifera* (4.47 μg/mL) and *Oroxylum indicum* (4.48 μg/mL) leaf extracts, indicating stronger anti-inflammatory effects of the plant-based NPs, in Table 3. The enhanced anti-inflammatory activity may be attributed to the presence of bioactive compounds in the plant extracts, including flavonoids, isothiocyanates, eugenol, ursolic acid, and phenolic acids, which are known for their potent anti-inflammatory properties. The synergistic action between these phytochemicals and MgO NPs likely contributes to the observed improvement in activity. This enhanced effect is likely due to

the combined anti-inflammatory action of the MgO NPs and the phytochemicals present in both plant extracts.

Acid neutralizing activity

The acid-neutralizing capacity of the standard antacid drug Siloxogene is 20.2 mEq/g, which is lower than that of green-synthesized MgO NPs from *Moringa oleifera* (22.54 mEq/g) and *Oroxylum indicum* (22.06 mEq/g) leaf extracts. This approach evaluates acid-neutralizing capacity in milliequivalents per gram (mEq/g), with higher values indicating stronger neutralization capabilities. The superior acid-neutralizing ability of these MgO NPs may be attributed to their nanoscale structure and the stabilizing properties provided by plant-derived compounds, which enhance surface reactivity and dispersion in acidic environments. While MgO NPs synthesized from *Oroxylum indicum* have slightly lower capacity than those from *Moringa oleifera*, they still demonstrate significant potential as effective antacid agents (Varghese and Das, 2022).

Table 1. Antioxidant Activity (% Inhibition) and IC_{50} Values of Synthesized MgO NPs with Standard Ascorbic Acid

Samples	**% Radical Scavenging Activity (±SD)**							**IC_{50} µg/mL**
	62.5 µg/mL	**31.25 µg/mL**	**15.63 µg/mL**	**7.81 µg/mL**	**3.91 µg/mL**	**1.95 µg/mL**	**0.98 µg/mL**	
Ascorbic acid	75.74 ± 0.001	75.51 ± 0.000	75.28 ± 0.001	75.06 ± 0.002	72.79 ± 0.001	50.11 ± 0.002	47.85 ± 0.002	1.90
MgO NPs (*M.oleifera*)	69.37 ± 0.002	54.83 ± 0.001	53.11 ± 0.001	52.78 ± 0.002	51.85 ± 0.001	51.05 ± 0.003	49.67 ± 0.002	1.21
MgO NPs (*O.indicum*)	68.78 ± 0.003	59.66 ± 0.002	54.23 ± 0.001	52.64 ± 0.002	51.65 ± 0.001	51.19 ± 0.003	49.73 ± 0.003	1.16

Table 2. Antidiabetic Activity (% Inhibition) and IC_{50} Values of Synthesized MgO NPs with Standard Metformin Drug

Samples	**% α-amylase Inhibition Activity (±SD)**							**IC_{50} µg/mL**
	125 µg/mL	**62.5 µg/mL**	**31.25 µg/mL**	**15.625 µg/mL**	**7.8125 µg/mL**	**3.91 µg/mL**	**1.95 µg/mL**	
Metformin drug	59.94 ± 0.000	59.09 ± 0.000	58.81 ± 0.000	57.39 ± 0.000	52.27 ± 0.001	50.28 ± 0.001	45.74 ± 0.001	3.79
MgO NPs (*M.oleifera*)	61.36 ± 0.001	61.08 ± 0.001	59.94 ± 0.000	57.67 ± 0.001	51.99 ± 0.002	48.58 ± 0.001	40.34 ± 0.003	5.54
MgO NPs (*O.indicum*)	59.09 ± 0.001	55.97 ± 0.000	55.40 ± 0.001	52.84 ± 0.000	51.99 ± 0.001	49.43 ± 0.001	42.80 ± 0.000	4.78

Table 3. Anti-inflammatory Activity (% Inhibition) and IC_{50} Values of Synthesized MgO NPs with Standard Diclofenac Sodium Drug

Samples	% Inhibition of Albumin Denaturation Activity (±SD)							IC_{50} µg/mL
	125 µg/mL	62.5 µg/mL	31.25 µg/mL	15.625 µg/mL	7.8125 µg/mL	3.91 µg/mL	1.95 µg/mL	
Diclofenac sodium drug	84.39 ± 0.001	83.84 ± 0.002	81.91 ± 0.001	76.68 ± 0.002	56.20 ± 0.001	33.06 ± 0.001	10.56 ± 0.003	6.77
MgO NPs (*M.oleifera*)	88.43 ± 0.001	87.60 ± 0.001	83.38 ± 0.001	77.59 ± 0.003	71.72 ± 0.004	46.37 ± 0.002	35.28 ± 0.006	4.47
MgO NPs (*O.indicum*)	88.07 ± 0.002	86.24 ± 0.001	84.39 ± 0.001	81.65 ± 0.001	68.81 ± 0.003	46.19 ± 0.002	34.25 ± 0.002	4.48

Table 4. Acid Neutralizing Capacity of Synthesized MgO NPs with Standard Siloxogene Antacid Drug

Sample	Milliequivalent per gram of antacid activity (mEq/g) (±SD)
Siloxogene	20.20 ± 0.173
MgO NPs (*M. oleifera*)	22.54 ± 0.153
MgO NPs (*O. indicum*)	22.06 ± 0.200

Conclusion

Green-synthesized MgO nanoparticles using *Moringa oleifera* and *Oroxylum indicum* extracts exhibit promising antioxidant, antidiabetic, anti-inflammatory, and acid-neutralizing activities, with *Oroxylum indicum* based NPs showing slightly higher efficacy, likely due to its richer phytochemical profile. SEM-EDX and FTIR analyses revealed that the choice of plant extracts influence nanoparticle's morphology, elemental composition, and surface chemistry, with *Moringa oleifera* showing more complex interactions. TG-DTA results show that MgO NPs synthesized from *Moringa oleifera* decompose in multiple stages, while MgO NPs synthesized from *Oroxylum indicum* undergo a more direct decomposition, indicating fewer organic residues. XRD analysis confirmed that both MgO NPs retained a cubic crystal structure, with slight differences in crystallite size (10.39 nm for *Moringa oleifera* and 14.03 nm for *Oroxylum indicum*), affecting their surface area, reactivity, and stability. Notably, *Moringa oleifera*-based MgO NPs exhibited a more ideal face-centered cubic structure, potentially enhancing their capping efficiency and surface interactions. This study highlighted the role of plant extracts in enhancing NP properties without altering MgO's intrinsic optical characteristics, making them viable for biomedical and catalytic applications. While the study suggests that *Moringa oleifera*-based MgO NPs interact more effectively as capping agents, further research is needed to

confirm this conclusively. These differences concluded how plant extracts influence the crystallinity, morphology, composition, and potential applications of MgO NPs.

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Suggested Questions Based on the Study

1. Questions on Green Synthesis and Phytochemical Influence

- How do the phytochemical compositions of *Moringa oleifera* and *Oroxylum indicum* influence the synthesis of MgO nanoparticles?
- Why do MgO NPs synthesized using *Oroxylum indicum* extracts show slightly higher efficacy in bioactivities?
- What role do plant extracts play in determining the morphology and elemental composition of MgO NPs?
- How does the choice of plant extract affect the surface chemistry of the synthesized MgO NPs?

2. Questions on Structural and Thermal Properties

- What are the key differences in the decomposition patterns of MgO NPs synthesized from *Moringa oleifera* and *Oroxylum indicum* based on TG-DTA analysis?
- How does the crystallite size variation (10.39 nm for *Moringa oleifera* and 14.03 nm for *Oroxylum indicum*) impact the surface area, reactivity, and stability of the nanoparticles?
- Why do MgO NPs synthesized from *Moringa oleifera* exhibit a more ideal face-centered cubic (FCC) structure?
- What are the implications of organic residue differences between the two synthesized MgO NPs?

3. Questions on Functional and Biomedical Applications

- How do the antioxidant, antidiabetic, anti-inflammatory, and acid-neutralizing activities of MgO NPs compare between the two plant-based synthesis methods?
- Why are MgO NPs considered promising for biomedical and catalytic applications?
- How does the capping efficiency of *Moringa oleifera*-based MgO NPs affect their stability and interactions?

4. Questions on Future Research and Optimization

- What further studies are needed to confirm the capping efficiency of *Moringa oleifera*-based MgO NPs?
- How can the synthesis process be optimized to maximize the beneficial properties of MgO NPs?
- What potential improvements could be made to enhance the stability and bioactivity of the synthesized MgO nanoparticles?

These questions can guide discussions and future research directions. Let me know if you need more specific ones!