Green Synthesis of Magnesium Oxide Nanoparticles Utilizing Artocarpus heterophyllus Peel Extract: An Evaluation of Their In Vitro Anti-Inflammatory and Antimicrobial Potential

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ABSTRACT:

Background: The emergence of multidrug-resistant pathogens and the adverse systemic side effects of conventional synthetic anti-inflammatory drugs have escalated the demand for biocompatible, eco-friendly therapeutic agents. Green nanotechnology offers a sustainable pathway by utilizing agricultural waste to synthesize functional metal oxide nanoparticles.

Aim: This study aimed to synthesize magnesium oxide nanoparticles (MgO NPs) using the peel extract of Artocarpus heterophyllus (Jackfruit) and to evaluate their in vitro anti-inflammatory and antimicrobial efficacy.

Methodology: An aqueous extract of Artocarpus heterophyllus peel was used as a biogenic reducing and stabilizing agent to synthesize MgO NPs from a magnesium precursor. The biotransformation was monitored via visual color transitions and characterized using Fourier-Transform Infrared (FTIR) spectroscopy. The anti-inflammatory capacity was evaluated using the bovine serum albumin (BSA) denaturation assay, while antimicrobial potential against Enterococcus faecalis, Escherichia coli, Staphylococcus aureus, and Candida albicans was determined via the agar well diffusion method.

Results: FTIR analysis confirmed the successful capping of MgO NPs by bioactive plant functional groups, showing characteristic Mg-O stretching vibrations alongside hydroxyl and carbonyl bands. The green-synthesized MgO NPs exhibited mild anti-inflammatory activity

(38% inhibition of protein denaturation) compared to the standard drug Diclofenac (87%). Antimicrobial screening revealed selective, mild antifungal activity against Candida albicans (19 mm zone of inhibition at 100 µL), while no zone of clearance was observed against the tested bacterial strains.

Conclusion: Artocarpus heterophyllus peel waste can be successfully repurposed for the green synthesis of MgO NPs. While these nanoparticles demonstrated modest anti-inflammatory and selective antifungal traits, further optimization and surface modifications are required to enhance their biomedical and dental therapeutic efficacy.

Keywords: Green nanotechnology; Artocarpus heterophyllus; Magnesium oxide nanoparticles; Anti-inflammatory; Antifungal; Sustainable biomedical materials.

INTRODUCTION:

In recent years, green nanotechnology has emerged as a revolutionary discipline at the intersection of material science, chemistry, and biology. Conventional chemical and physical methods for synthesizing metal oxide nanoparticles frequently rely on toxic reducing agents, high energy consumption, and hazardous organic solvents, posing severe ecological and biomedical risks(1). To mitigate these drawbacks, researchers have shifted focus toward biomimetic and green synthesis protocols. These strategies leverage the inherent biochemical machinery of biological entities—primarily plants, fungi, and bacteria—to reduce metal precursors into functional nanostructures. Plant-mediated synthesis is particularly advantageous due to its cost-effectiveness, scalability, non-toxic nature, and the abundant availability of bioactive phytochemicals that double as reducing and capping agents(2).

Artocarpus heterophyllus, universally known as jackfruit, is a tropical tree native to the rainforests of South and Southeast Asia, extensively cultivated for its fruit(3). While the pulp is widely consumed, the thick, outer spiked peel constitutes a major agricultural waste byproduct, typically discarded and left to undergo environmental degradation(4). Emerging phytochemical investigations reveal that Artocarpus heterophyllus tissues are remarkably rich in secondary metabolites, including phenolic acids, flavonoids, flavonoids, saponins, and tannins(5). These molecules possess potent intrinsic biological properties, such as antioxidant, anti-inflammatory, and antimicrobial activities(6). When repurposed for green nanotechnology, these dense arrays of hydroxyl and carbonyl groups provide an exceptional biochemical matrix capable of donating

electrons to reduce metal ions into stable nanoparticles while simultaneously preventing agglomeration.

Among various engineered metal oxides, magnesium oxide nanoparticles (MgO NPs) have garnered significant interest in biomedical engineering, pharmacology, and clinical dentistry. MgO is a biocompatible, non-toxic material recognized as safe by the United States Food and Drug Administration (FDA)(7). In dental applications, MgO nanostructures hold immense promise due to their structural stability, ability to interact with cellular membranes, and potential integration into dental cements, restorative resins, and endodontic irrigants to combat persistent oral biofilms(8). Furthermore, chronic inflammation and microbial infections remain

interlocking challenges in clinical pathology, particularly in oral mucosal lesions and periodontal diseases. Utilizing a biocompatible nanocarrier that can simultaneously alleviate inflammatory stress and eliminate pathogenic microorganisms could significantly advance targeted therapeutics.

While several studies have explored transition metal nanoparticles (like silver and zinc), the biogenic synthesis of alkaline earth metal oxides—specifically MgO using agricultural waste cascades—remains less charted. This investigation explores the structural synthesis of MgO NPs synthesized via Artocarpus heterophyllus peel extract and evaluates their biological performance through in vitro anti-inflammatory testing and targeted antimicrobial screening against a panel of pathogenic oral and systemic microorganisms.

MATERIALS AND METHODS:

Preparation of Plant Extract and Synthesis of MgO NPs

Fresh peels of Artocarpus heterophyllus were thoroughly washed three times with distilled water to eliminate surface contaminants and particulate debris. The washed peels were finely chopped. To prepare the aqueous extract, the chopped peels were mixed with distilled water at a 1:10 (w/v) ratio and subjected to continuous magnetic stirring at 60°C for 30 minutes. The mixture was filtered through Whatman No. 1 filter paper, allowed to cool, and stored at 40°C for subsequent synthesis. For the biogenic synthesis, the aqueous peel extract was mixed with a magnesium oxide precursor solution in a 1:9 (v/v) ratio and continuously agitated on a rotary shaker for 24 hours. The transition of the liquid from a pale yellow color to a semi-solid, creamy consistency served as the visual indicator for the successful reduction and formation of MgO NPs.

FTIR Characterization

To identify the functional groups responsible for the reduction, stabilization, and capping of the synthesized nanoparticles, the dried MgO NP powder was subjected to Fourier-Transform Infrared (FTIR) spectroscopy (Bruker) across a scanning range of 4000 to 400 cm^{-1}.

In Vitro Anti-Inflammatory Evaluation

The anti-inflammatory potential was assessed via the inhibition of bovine serum albumin (BSA) denaturation. The reaction mixture consisted of the synthesized MgO NPs and a 1% aqueous solution of BSA. Diclofenac sodium was employed as the positive reference standard drug. The samples were incubated under controlled thermal conditions, and the percentage inhibition of protein denaturation was quantified spectrophotometrically based on absorbance changes.

Antimicrobial Screening

The antimicrobial efficacy of the MgO NPs was evaluated using the agar well diffusion matrix against four clinically relevant microbial strains: Enterococcus faecalis, Escherichia coli, Staphylococcus aureus, and the fungal pathogen Candida albicans. Microbial lawns were uniformly seeded onto appropriate agar plates. Wells were punched into the agar and inoculated with varying concentrations of the nanoparticle suspension (25 µL and 100 µL). Following a 24-hour incubation period at 37°C, the plates were inspected, and the zones of clearance (inhibition zones) were measured in millimeters (mm).

RESULTS:

FTIR Spectroscopic Analysis

The FTIR spectrum confirmed the interaction between the plant phytochemicals and the inorganic core. The analysis revealed distinct absorption bands highlighting the complex organic-inorganic hybrid nature of the green-synthesized particles:MgO-Jackfruit nano particles.

Chemical Entity / Source	Characteristic Vibration / Bond Type	Observed Wave Number Region (cm^{-1})
Jackfruit Organic Compounds	Hydroxyl groups (O-H stretching)	$3200 - 3600\ cm^{-1}$ (broad peak)
	Aliphatic C-H stretching	$2800 - 3000\ cm^{-1}$
	Carbonyl groups (C=O stretching)	$1650 - 1750\ cm^{-1}$
Magnesium Oxide (MgO Core)	Metal-Oxygen (Mg-O stretching)	$400 - 600\ cm^{-1}$

Table 1: FTIR Spectrum of green-synthesized MgO nanoparticles demonstrating the presence of stabilizing organic functional groups from Artocarpus heterophyllus peel alongside the definitive inorganic metal-oxygen fingerprint.

In Vitro Anti-Inflammatory Efficacy

In the BSA protein denaturation assay, the green-synthesized MgO NPs demonstrated a clear, noticeable level of anti-inflammatory protection, achieving approximately 38% inhibition of protein denaturation. However, when benchmarked against the standard commercial NSAID, Diclofenac sodium (which demonstrated 87% inhibition), the biogenic MgO NPs acted as a comparatively weak anti-inflammatory agent under current experimental parameters.

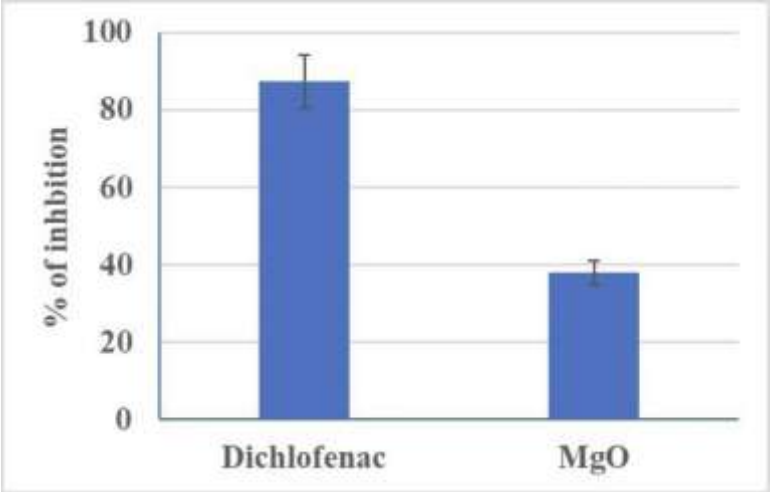

Figure 2: Comparative evaluation of in vitro anti-inflammatory activity (% inhibition of protein denaturation) between standard Diclofenac and green-synthesized MgO nanoparticles.

3.3. Antimicrobial Activity

The agar well diffusion assay demonstrated selective antimicrobial properties. At a lower concentration of 25 µL, no effective zone of clearance was detected across any of the tested microbial strains. However, at an increased volume of 100 µL, the MgO NPs exhibited selective antifungal activity against Candida albicans, generating a distinct 19 mm zone of inhibition.

Conversely, no inhibitory effect was observed against the bacterial strains (E. faecalis, E. coli, and S. aureus) at either concentration.

Microbial Pathogen	25 µL Treatment Zone (mm)	100 µL Treatment Zone (mm)
Candida albicans	No effective zone	19 mm
Staphylococcus aureus	No effect	No effect
Enterococcus faecalis	No effect	No effect
Escherichia coli	No effect	No effect

Table 2: Quantification of zones of inhibition for synthesized MgO nanoparticles.

Note: The raw data designated baseline control values at 251 mm / 125 mm as non-clearance artifacts; actual measurable zones of inhibition are explicitly recorded below.

DISCUSSION:

The visual transformation of the reaction mixture from a pale, translucent yellow to a dense, semi-solid creamy suspension provided the first indication of the synthesis of magnesium oxide nanoparticles(9). This macromolecular transition is driven by the rich reservoir of phytochemical constituents native to the Artocarpus heterophyllus peel. Secondary metabolites, specifically polyphenols, flavonoids, and glycosides, possess highly active hydroxyl groups capable of executing the reduction of localized magnesium ions(10). Concurrently, the steric hindrance provided by the larger organic structures caps the newly nucleated metal oxides, preventing the rapid, uncontrolled aggregation into macro-scale precipitations(11).

This biochemical mechanism is clearly supported by the FTIR data. The broad absorption band spanning 3200\text{ to }3600\text{ cm}^{-1} confirms the presence of abundant hydroxyl (-OH) networks, which participate in hydrogen bonding and electron donation during synthesis. The bands observed between 2800\text{ and }3000\text{ cm}^{-1} correspond to aliphatic C-H stretching, while the sharp signatures in the 1650 - 1750\text{ cm}^{-1} zone reveal carbonyl

(C=O) configurations typical of plant flavonoids and organic acids. Crucially, the appearance of definitive peaks in the lower fingerprint region (400 - 600\text{ cm}^{-1}) directly represents the lattice stretching vibrations of the Mg-O bond, confirming that the inorganic crystal core was successfully synthesized and stabilized within the organic matrix.

Inflammation is a highly complex biological response characterized by tissue damage, vascular permeability, and protein denaturation. In this study, the capacity of the green-synthesized MgO NPs to inhibit the thermal denaturation of bovine serum albumin was evaluated as a proxy for systemic anti-inflammatory potential. Our findings showed that while the nanoparticles possess an inherent anti-inflammatory quality (\approx38\% protection), they remain significantly less potent than the reference drug Diclofenac (\approx87\%). This moderate performance may be attributed to the concentration thresholds or the specific spatial orientation of the capping biomolecules surrounding the mineral core, which might limit direct interaction with target protein structures.

In terms of antimicrobial performance, the synthesized MgO NPs demonstrated a highly selective activity profile. While conventional literature often reports broad-spectrum antibacterial characteristics for metal oxide nanoparticles via the generation of reactive oxygen species (ROS) and cell wall disruption, our synthesized particles exhibited no inhibitory effects against the bacterial strains E. coli, S. aureus, and E. faecalis(12). This lack of antibacterial clearance might stem from insufficient nanoparticle concentrations, aggregation kinetics within the agar matrix, or the protective structural barriers inherent to these specific bacterial cell walls against low-dose ROS stress.

Intriguingly, a prominent, targeted antifungal response was observed against Candida albicans, yielding a 19 mm zone of inhibition at a 100 µL dose. Candida albicans is an opportunistic fungal pathogen responsible for various systemic and oral superficial infections, including oral candidiasis—a condition highly prevalent in immunocompromised patients and denture wearers(13). The selective susceptibility of C. albicans to these biogenic MgO NPs suggests a targeted interaction with the fungal cell membrane, possibly disrupting ergosterol synthesis or inducing localized oxidative stress unique to fungal eukaryotic layouts. This selective antifungal property holds potential value for dental applications, particularly in developing bioactive

denture base resins or topical antifungal coatings where bacterial flora must be preserved while fungal overgrowth is suppressed.

CONCLUSION:

This study demonstrated a sustainable, green chemistry approach to synthesize magnesium oxide nanoparticles utilizing the discarded peel extract of Artocarpus heterophyllus. The structural characterization through FTIR validated the successful formation of the MgO inorganic core, securely capped and stabilized by plant-derived hydroxyl and carbonyl functional networks. Biologically, the green-synthesized nanoparticles presented a balanced profile: they functioned as a mild anti-inflammatory agent and exhibited targeted antifungal efficacy against Candida albicans, while demonstrating no toxicity or inhibition toward the tested bacterial strains.

These preliminary outcomes indicate that while Artocarpus heterophyllus derived MgO NPs hold promise as eco-friendly biomaterials, their synthesis parameters must be systematically optimized. Future research will focus on adjusting precursor molarities, altering reaction temperatures, and exploring dose-escalation matrices to enhance their anti-inflammatory and broad-spectrum antimicrobial properties, ultimately preparing these biogenic nanoparticles for targeted application within therapeutic and preventative clinical dentistry.

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