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Green Synthesis of Calcium Oxide Nanoparticles using Ananas Comosus Peel Extract

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Abstract

The synthesis of calcium oxide (CaO) nanoparticles using eco-friendly and sustainable methods has gained significant attention due to its cost-effectiveness and reduced environmental impact. In this study, CaO nanoparticles were successfully synthesized using Ananas comosus (pineapple) peel extract as a natural reducing and stabilizing agent. The green synthesis approach offers an alternative to conventional chemical methods, minimizing toxic by products. The synthesized CaO nanoparticles were characterized using various analytical techniques to determine their structural, optical, and morphological properties. X-ray diffraction (XRD) analysis confirmed the crystalline nature and phase purity of the nanoparticles. Ultraviolet-visible (UVVis) spectroscopy was employed to evaluate the optical properties and band gap energy. Fourier-transform infrared (FTIR) spectroscopy identified the functional groups involved in the synthesis process and confirmed the presence of CaO bonds. Field Emission Scanning Electron Microscopy (FE-SEM) revealed the surface morphology and particle size distribution of the nanoparticles. The results demonstrated that the green synthesis method effectively produced CaO nanoparticles with desirable physicochemical properties. These nanoparticles have potential applications in catalysis, water treatment, biomedical fields, and other industrial sectors.

Keywords: Calcium oxide, Ananas comosus peel, green synthesized Nanoparticles

I. INTRODUCTION

Nanotechnology has emerged as a transformative field, offering innovative solutions across diverse scientific disciplines. Among various nanomaterials, calcium oxide (CaO) nanoparticles have garnered significant attention due to their wide-ranging applications in catalysis, antimicrobial agents, environmental remediation, and biomedical fields. Traditionally, the synthesis of CaO nanoparticles has relied on physical and chemical methods, which often involve toxic reagents, high energy consumption, and environmentally hazardous by-products. These limitations have prompted the development of sustainable and eco-friendly synthesis approaches. Green synthesis, which utilizes biological resources such as plant extracts, microorganisms, or natural polymers, has emerged as a promising alternative. This method not only eliminates the need for harmful chemicals but also leverages the reducing and stabilizing properties of bioactive compounds present in natural sources. The use of plant extracts, in particular, offers simplicity, cost-effectiveness, and scalability, making it suitable for large-scale production of nanoparticles. The present study focuses on the green synthesis of calcium oxide nanoparticles using plant-based extracts, aiming to achieve a biocompatible, environmentally benign, and economically viable approach. This method aligns with the principles of green chemistry and addresses the pressing need for sustainable nanomaterial production. The synthesized CaO nanoparticles are characterized for their structural, morphological, and functional properties, with a view toward potential applications in antibacterial activity and environmental applications.

II. MATERIALS AND METHODS

1. Preparation of pineapple peel aqueous extract.

Pineapple peels (50 g) were weighed and added to 150 mL of distilled water. The mixture was then boiled at 100 °C for 30 minutes to extract phytochemicals and other soluble constituents. After boiling, the solution was cooled to ambient temperature and filtered using standard filtration techniques to obtain a clear extract, which was subsequently stored for further analysis.

2. Production of caO nanoparticles.

A green synthesis approach was employed for the preparation of calcium-based nanomaterials. Initially, 1 g of calcium oxide was dissolved in 20 mL of distilled water. The solution was heated to 80 °C under continuous stirring to facilitate dispersion. To this, 10 mL of pineapple peel extract was added and the pH of the mixture was adjusted to 7 using 150 ml sodium hydroxide is added drop by drop. The resulting solution was then boiled for 2 hours, during which a white precipitate was observed. The precipitate was collected by centrifugation. Finally, the purified precipitate was dried in a hot air oven at 100 °C to obtain the calcium-based nanomaterial.

III. RESULTS AND DISCUSSIONS

1. XRD ANALYSIS

X-ray diffraction (XRD) is a powerful technique used to determine the crystalline structure, phase purity, and crystallite size of synthesized nanoparticles.

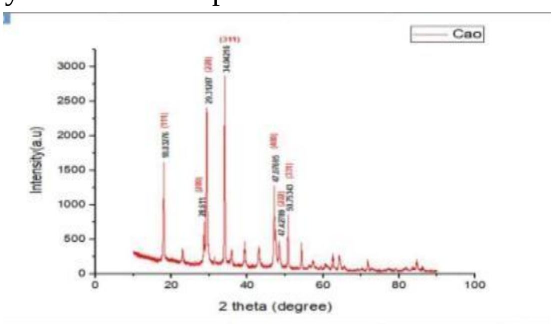

Fig.1 XRD spectrum for calcium oxide nanoparticle

The X-ray diffraction (XRD) pattern of the synthesized CaO nanoparticles shows prominent peaks at 2θ = 29.37°, 31.04°, and 47.07°, corresponding to the (220), (311), and (400) planes, respectively, indicating a crystalline cubic phase. The average crystallite size was calculated using the Scherrer equation, where the most intense peak at 2θ = 29.37° was considered. Assuming a shape factor (K) of 0.9 and a Cu Kα radiation (λ = 0.15406 nm), the estimated crystallite size is approximately **25 nm**.

2. FTIR SPECTROSCOPY

The image shows an infrared (IR) spectrum, which is typically used in Fourier Transform infrared Spectroscopy (FTIR) analysis to identify functional groups in a sample. 3641.60 cm⁻¹. This peak corresponds to the O-H stretching vibration, indicating the presence of hydroxyl (- OH) groups from water or organic compounds in 1408.04 cm⁻¹. This peak is associated with the C=O stretching of carboxylates or other carbonyl-containing compounds. 1076.28 cm⁻¹. This corresponds to C– O stretching, often found in polysaccharides, esters, or phenolic compounds present in plant extracts. 871.82 cm⁻¹ and 709.80 cm⁻¹. These peaks are characteristic of the Ca–O bond, confirming the presence of calcium oxide nanoparticles. 420.48 cm⁻¹ region. This is a significant region for metaloxygen (Ca–O) vibrations, further supporting the formation of calcium oxide nanoparticles. The CaO stretching vibrations confirm the successful formation of calcium oxide nanoparticles. If the goal is to obtain pure CaO, additional calcination at high temperatures (above 800°C) may be required to remove remaining carbonate impurities.

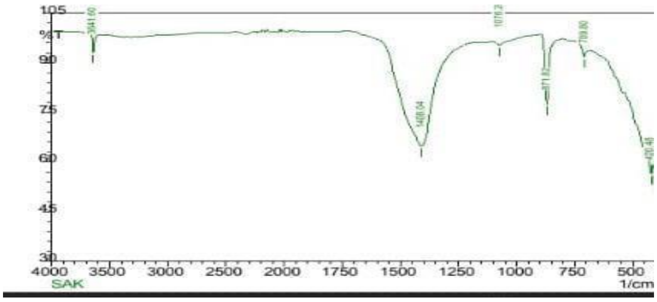

Fig .2 FTIR spectrum for calcium oxide nanoparticles

Wavenumber(cm⁻¹)	Bond type	Vibration
3641.60	O-H	Hydroxyl(stretching) from water or organic compounds
1408.04	C=O	Carbonyl(stretching) from carboxylate or organic acids
1076.28	C-O	C-O stretching from polysaccharides, esters, or phenolic compounds
871.82	Ca-O	Calcium oxide vibration
709.80	Ca-O	Calcium oxide vibration
420.48	Ca-O	metal-oxygen (Ca-O) stretching vibration

Table: 1 FTIR spectrum for calcium oxide nanoparticles

3. UV ANALYSIS

UV-Vis absorption spectrum, which is used to analyze the optical properties of a sample, typically identifying electronic transitions in molecules.

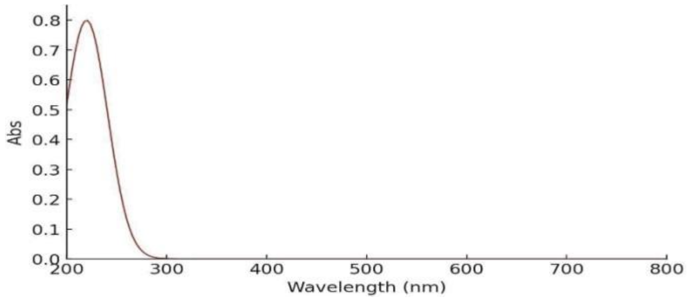

Fig.3 UV-Vis Analysis

And the X-Axis (Wavelength in nm): The spectrum ranges from 200 nm to 800 nm, which covers both the ultraviolet (UV) and visible regions. Y-Axis (Absorbance, Abs): The absorbance values range from 0 to ~0.8. A strong absorption peak occurs around 250-280 nm, with a maximum absorbance (~0.8). The absorbance rapidly declines after this peak and approaches zero beyond 300 nm. This indicates that the material could be a wide-bandgap semiconductor like ZnO (~3.3 eV), TiO_2 (~3.0 eV), or an organic molecule with strong UV absorption.

4 . FIELD EMISSION- SCANNING ELECTRON MICROSCOPE (FE-SEM)

FE-SEM provides detailed images of the size, shape, and surface structure of nanoparticles, helping researchers understand the effects of synthesis conditions on nanoparticle morphology. It can be used to measure the size distribution of nanoparticles, which is crucial for ensuring uniformity in synthesized nanoparticles.

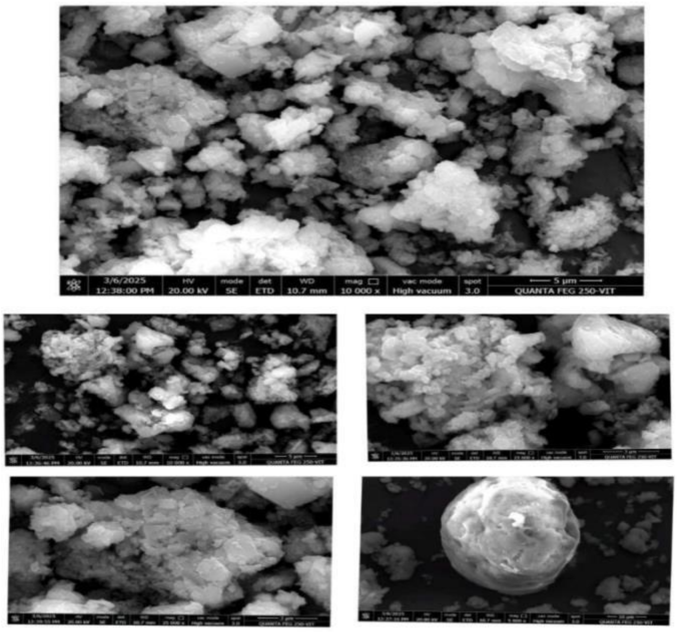

Fig.4 FE-SEM Analysis

Fe- SEM images of the Fe-based material, captured at 10,000× magnification using QUANTA FEG 250-VIT, reveal irregular, agglomerated particles with rough surfaces. The morphology shows porous, sponge-like structures and some spherical formations, indicating possible sintering or encapsulation.

The particle size ranges from submicron to a few microns, suggesting high surface area, which is advantageous for catalytic and adsorption applications.

5. EDX

The Electron Image (SEM) shows a selected analysis area where Energy Dispersive Spectroscopy (EDS) was performed.

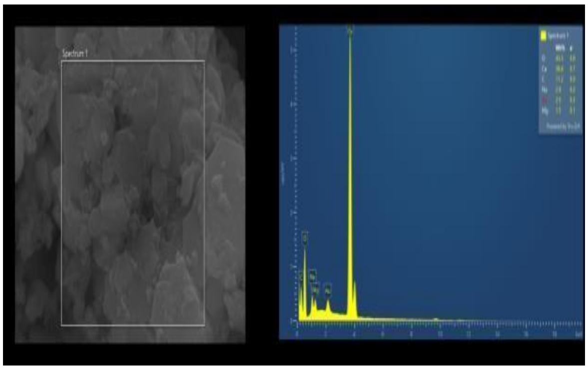

Fig. 5 EDX Analysis

EDX results show dominant Calcium, Oxygen, and Carbon, indicating the presence of $CaCO_3$ or CaO**.** Minor elements like Na, Al, and Mg suggest impurities or secondary phases**.** Iron (Fe) was not detected, implying low concentration or dominance of Ca-based compounds. The data suggests a calcium-based material with possible surface contamination or mixed-phase composition**.**

IV. Conclusion

Calcium oxide (CaO) nanoparticles were successfully synthesized using Ananas comosus peel extract via a green synthesis approach. XRD confirmed their polycrystalline cubic structure with an average size of ~25 nm. FT-IR analysis verified the role of plant biomolecules as reducing and capping agents, while UV–Vis spectroscopy showed strong optical activity between 250–280 nm. FE-SEM revealed predominantly spherical nanoparticles with uniform morphology. This ecofriendly, cost-effective method highlights the potential of agricultural waste in nanomaterial synthesis and opens avenues for biomedical, environmental, and industrial applications.

V. ACKNOWLEDGEMENT

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