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Green Synthesis of Calcium Oxide Nanoparticles and Its Applications

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ABSTRACT
Green synthesis of metal oxide nanoparticles is gaining considerable interest due to the use of environmentally friendly reactants and room temperature synthesis. This is the most preferred method of preparation as it makes use of pollution free chemicals and encourages the use of non-toxic solvents such as water and plants extracts. The present study is proposed with an objective to synthesize CaO nanoparticles by the eco-friendly green synthesis using environmentally benign papaya leaf extract and Green Tea extract. The obtained CaO nanoparticles have been characterized by UV- Vis, Fourier Transform Infrared (FTIR) X-ray Diffraction (XRD), and Scanning Electron Microscopy (SEM) studies. The antibacterial and photocatalytic activity of the calcium oxide nanoparticles were also analysed.
Keywords: CaO nanoparticles, Green Synthesis, Green Tea Extract, Papaya Leaf extract,

I. INTRODUCTION

The use of plant extracts in the synthesis of nanoparticles have proven to be cost effective and opens up a wide area in non-toxic nanoparticle synthesis. Calcium Oxide (CaO) nanoparticles have found several applications such as in catalysis, adsorption, water purification and also as antibacterial agents [1-3]. CaO is of particular interest as it is regarded as a safe material to human beings and animals. There are many reports on preparation of Calcium oxide nanoparticles from chemical methods. However, only few biogenic syntheses are being reported in literature [4-6]. In this work, CaO nanoparticles was synthesised using the Papaya Leaf and Green Tea extract. Then the as prepared CaO NPs prepared were characterized using UV-Vis spectroscopy, Fourier Transform Infrared (FT-IR), Powder X-ray Diffraction studies (XRD), Scanning Electron Microscopy (SEM) techniques. The applications such as antibacterial and photo catalytic activity for the same were studied.

II. MATERIALS AND METHODS

Calcium nitrate, ($Ca(NO_3)_2$. $4H_2O$) from (HI Media), Sodium hydroxide pellets (Avra synthesis Pvt. Ltd), distilled water. The plant extracts used for synthesis of nanoparticles were prepared using plants such as papaya leaves collected from the botanical garden of Stella Maris College, Chennai. Green Tea leaves was purchased from the Nilgris super market.

2.1 Preparation of extract from Papaya leaves

Papaya extract was prepared from 100 g of thoroughly washed papaya leaves. It was then boiled in 200 mL of distilled water for half an hour, filtered with Whatmann no 1 filter paper and the resulting extract was cooled and used for synthesis of metal oxide nanoparticles.

2.2 Preparation of extract from Green Tea leaves

Green tea extract was prepared from 10 g of thoroughly washed green tea leaves. It was then boiled in 100 mL of distilled water for half an hour, filtered with Whatmann no 1 filter paper and the resulting extract was cooled and used as the green tea extract solution.

2.3 Synthesis of calcium oxide nanoparticles using plant extracts

Ten mL of calcium nitrate solution was added to 10 mL of papaya extract. Then, the mixture was stirred in a magnetic stirrer for about half an hour. NaOH was added dropwise while stirring till a white precipitate of calcium hydroxide was obtained. The precipitate was filtered and dried in an air oven for an hour. The content was washed repeatedly with distilled water to remove the basicity of the solution. Further, the calcination was done in the muffle furnace at 500^0C for three hours. Similar procedure was carried out for synthesis of calcium oxide nanoparticles using Green Tea extract.

III. RESULTS AND DISCUSSION

3.1 UV Diffused Reflectance Spectroscopy (UV-DRS)

The UV spectrum of CaGT and CaP nanoparticles are shown in Fig. 3.1.The band gap energy of the Calcium oxide nanoparticle was calculated using the Planck's equation. The band gap energy of CaO is found to be 3.44 eV and

3.48eV for CaGT and CaP nanoparticles respectively.

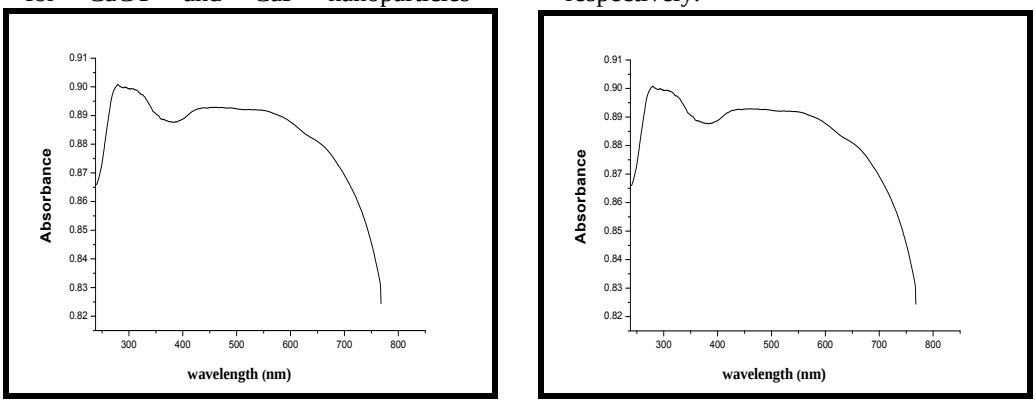

Fig. 3.1 UV (DRS) absorption spectrum of CaGT and CaP nanoparticles

3.2 Infrared Spectroscopy

The prepared calcium oxide nanoparticles (CaGT and CaP) were characterised using Perkin Elmer FT-IR spectrometer. The FT-IR spectra of CaGT and CaP are shown in Fig. 3. The sharp peak at 874cm-^{1} is due to the presence of Ca-O-Ca bonding and peak at 712cm-^{1} is due to the presence of Ca-O bonding which identifies the presence of calcium oxide. Broad IR bands at 3783, 2926, 1796, 1429 cm^{-1} show the presence of hydroxyl group, carboxylic group, amines and amides which confirms that the phytoconstituents could possibly enhance the stabilization of Calcium oxide nanoparticles.

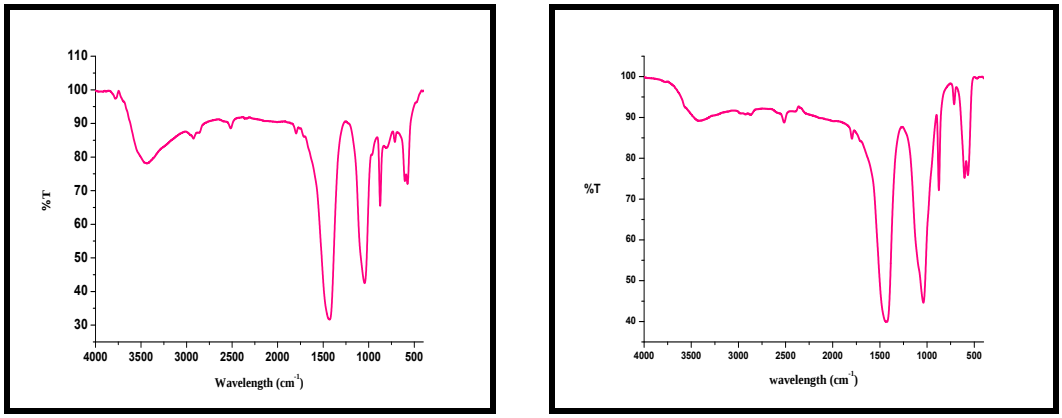

Fig. 3.2 FT-IR spectra of CaGT and CaP nanoparticles

3.3 Powder X-Ray Diffraction studies

The XRD pattern of CaO NPs are shown in Fig 4. The XRD pattern of CaO NPs shows good agreement with the standard JCPDS NO. 77-2376. The pure cubic phase of Calcium oxide was formed in both CaGT and CaP composite. The average crystallite size were determined by a the debye-Scherer formula and found to be 23 nm and 24 nm for CaGT and CaP respectively, which confirmed that the synthesized nanocomposites are nanocrystalline in nature.

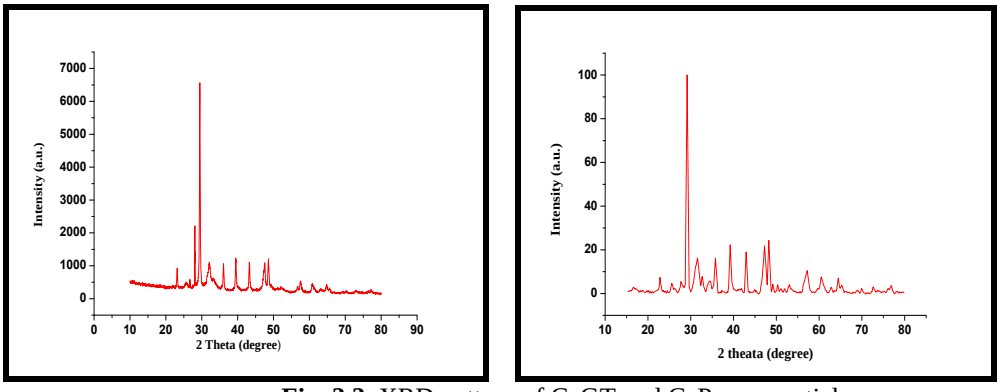

Fig. 3.3 XRD pattern of CaGT and CaP nanoparticles

3.4 Scanning Electron Microscopy

SEM images showed the particle size ranging from 86-117 nm for CaGT whereas for CaP, it ranged from 89-148 nm as shown in Fig 5. The SEM images of CaGT and CaP indicated agglomeration, which revealed that the synthesized nanoparticles are porous.

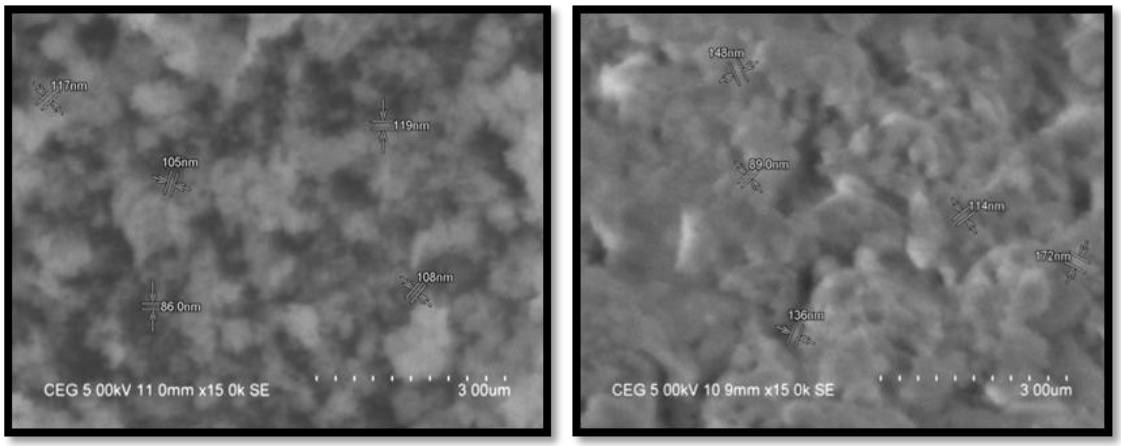

Fig. 3.4 SEM images of CaGT and CaP nanoparticles

3.5 Antibacterial Studies

Antibacterial activity of the synthesized Calcium oxide nanoparticles from Green Tea extract and papaya extract were studied using the disc-diffusion method.

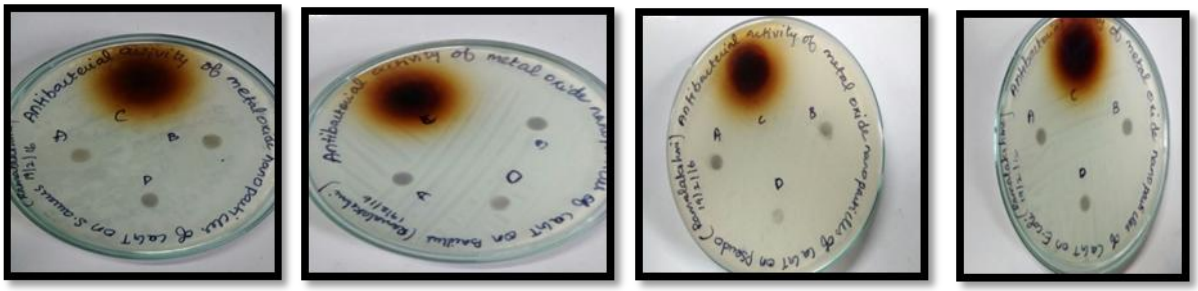

Fig. 3.5 Antibacterial activity of CaGT on S.*aureus*, B.*cereus*, E.*coli* and *P. aeruginosa*

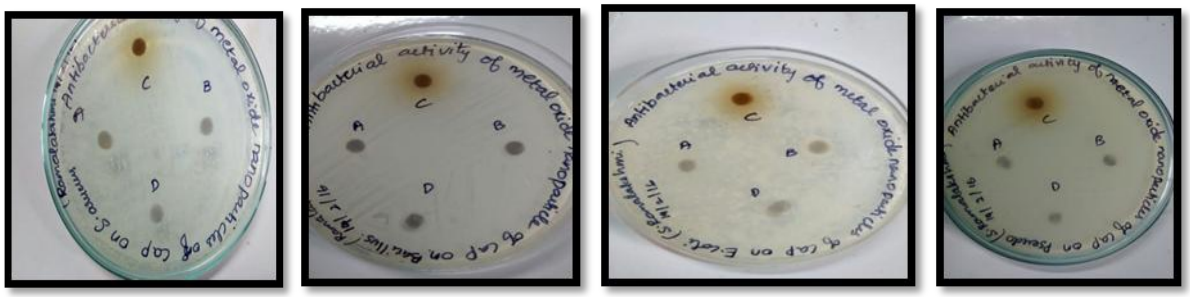

Fig.3. 6 Antibacterial activity of CaP on *S.aureus, B.cereus, E.coli and P. aeruginosa*

The synthesized calcium oxide nanoparticles which were placed on the surface of the bacteria medium –inoculated agar medium were measured for inhibition. A a 50 µl concentration of calcium oxide nanoparticles, B 100 µl concentration of calcium oxide nanoparticles, C positive control (Green Tea extract, papaya extract) and D negative control. The, synthesized nanoparticles showed inhibition in both gram positive and gram negative bacteria.

3.6 Photocatalytic Studies

The UV–Vis absorption curves of CaGT and CaP nanoparticles showing photocatalytic studies are represented in Fig 3.7 and Fig 3.8 respectively. The photocatalytic activity of the synthesized calcium oxide nanoparticles, CaGT and CaP were studied by degrading Congo red(CR) dye. To 100 mL of 25 ppm concentrated

dye, 100 mg of the catalysts (CaGT and CaP) were added and the degradation was carried out as mentioned above and the results were recorded.. Initially UV absorption of the CR dye is measured followed which the absorption is measured periodically at an interval of 30 min for 3 hrs with the addition of the catalyst. The Figure shows reduction in the absorption maximum between 350 nm and 500 nm which is a clear indication of the photocatalytic activity of CaGT and CaP nanoparticles.

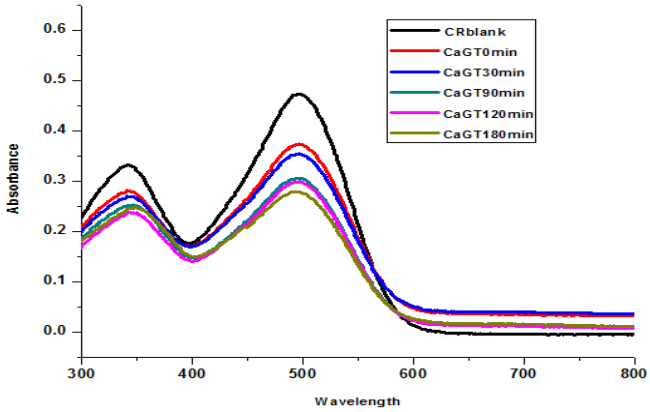

Fig 3.7 Photocatalytic degradation of Congo Red using CaGT nanoparticles

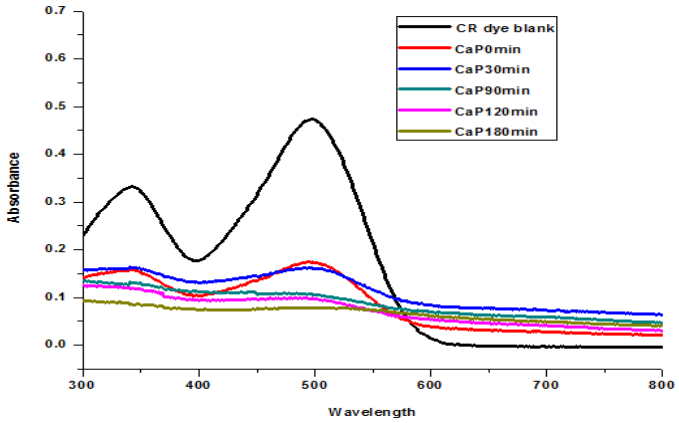

Fig 3.8 Photocatalytic degradation of Congo Red using CaP nanoparticles

3.6.1 Effect of Amount of CaGT and CaP Catalyst on Decolourization of CR

After equilibration time of 20 minutes, photocatalytic experiments were carried out for 3 hours. Concentration of CR at different time intervals was determined spectrophotometrically and the results are shown as a plot of $\ln(C/C_O)$ Vs time in Fig. 3.9 and 3.10 respectively, where C is the concentration at various time intervals and C_O the initial concentration. A linear fit plot was obtained which indicated that the reaction followed the pseudo first order rate kinetics. Rate constants were calculated from each linear plot. Increase in the pseudo first order rate constant with increase of CaP catalyst indicated that the decolourization was truly photocatalytic.

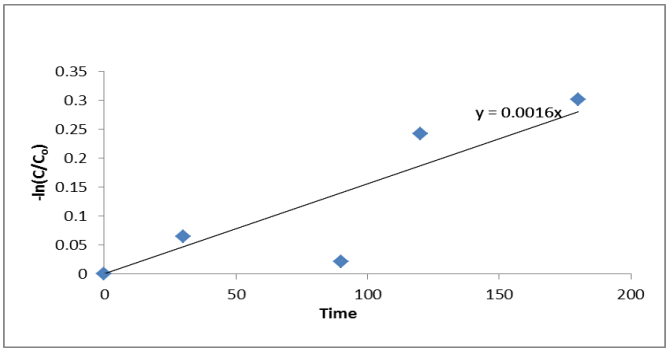

Fig 3.9 Plot of $\ln(C/C_o)$ Vs Time for the degradation of CR on CaGT nanoparticles

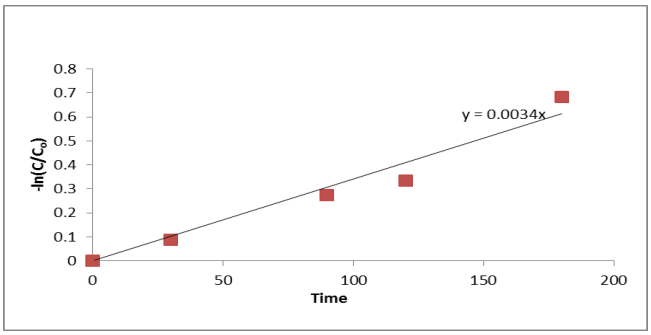

Fig 3.10 Plot of $\ln(C/C_0)$ Vs Time for the degradation of CR on CaP nanoparticles

3.6.2 Efficiency of the Photocatalytic behaviour of the as prepared Catalyst

A comparison of the efficiency of the photocatalytic behavior of CaGT and CaP were studied. It is observed from Fig (3.11) that CaP .has a higher photocatalytic activity when compared to CaP. This may be due to the high antioxidant property of papaya which is used as a stabilizing /capping agent in the synthesis of the catalyst. CaP prevents the recombination of electrons from the conduction band to the valence band thereby enhancing its photocatalytic activity than CaGT nanoparticles.

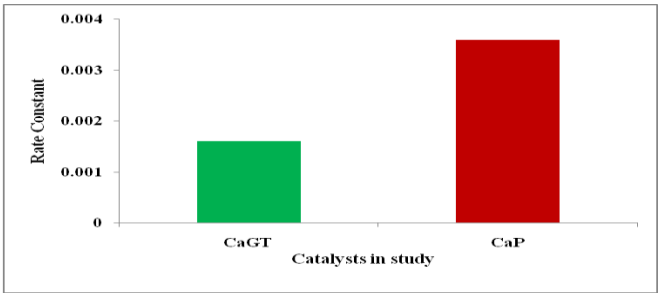

Fig 3.11 Plot of Rate Constant against CaGT and CaP nanoparticles

IV. CONCLUSION

The proposed study was undertaken for thee development of an economic and eco-friendly method of synthesizing CaO nanoparticles. The antibacterial studies of CaGT and CaP indicated that the synthesized nanoparticles showed sensitivity to both Gram negative and Gram positive bacteria. CaP nanoparticles showed higher photocatalytic activity than CaGT nanoparticles. Hence, calcium oxide nanoparticles synthesized using papaya leaves acts as an excellent photocatalyst in for degradation of dyes from textile industries.

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