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Synthesis, Characterisation and Antibacterial Activities of Calcium Oxide Nanoparticles by Precipitation Method

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Abstract

Calcium oxide (CaO) nanoparticles were comprehensively used as a catalyst in biodiesel production. Calcium oxide nanoparticles were prepared by using calciumhydroxide ($Ca(OH)_2$) and ethylene glycol ($C_2H_6O_2$) as precursor through precipitation method. The resultant calcium oxide nanoparticles were characterized by various techniques like, X-ray diffraction (XRD) reveals the average size of calcium oxide nanoparticles is found to be 19nm using Debye-Scherrer equation. Scanning electron microscopy (SEM) image displays that calcium oxide nanoparticles have hexagonal morphology. Energy- dispersive X-ray analysis (EDAX) exhibits the various concentration of calcium oxide. Fourier-transform infrared spectroscopy (FTIR) confirms the functional group of calcium oxide nanoparticles. The UV-Vis spectroscopy determines the band gap of calcium oxide nanoparticles and also the calcium oxide nanoparticles shows excellent antibacterial activity due to its degradation property..

Keywords: CaO nanoparticles, precipitation, XRD, Antibacterial activity.

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1. Introduction

Nanoparticles show some peculiar properties through its confined size and possess some properties like high surface area, optical properties and magnetic properties. Calcium oxide nanoparticles have great significance due to its wide spread application and natural availability. Calcium oxide is white caustic alkaline solid and it serves as crystalline solid at ambient temperature. It is also known as “BURNT LIME” or “QUICK LIME”. In order to get calcium oxide, the component is annealed strongly over 900°C to release Carbon-Di-Oxide; this process is usually known as calcination. The yearly worldwide quick lime production is over 280 million metric tons. When CaO is annealed to 2400°C, it emits lime light (intense glow). Calcium oxide is a principle ingredient for making cement and also it is obtained from natural resource like waste egg shell.[12] Calcium oxide acts as a heterogeneous base catalyst for the production of biodiesel.[11, 13] Calcium oxide is used to neutralize the acidic gases and remove SO_2 from flue gases. [6] This process is called flue gas desulfurization.[5] Calcium oxide nanoparticles play a vital role in degradation of chemical hazardous due to its intrinsic surface area and catalytic properties. So, there are called destructive adsorbents. Calcium oxide nanoparticles also implemented as pollution controlling agent due to its CO_2 capturing property and also in purification of hard gases.[15] Nanoscale calcium oxide can be prepared by various methods such as Sol-gel,[1] precipitation,[2] biosynthesis,[14] thermal decomposition[3] and hydrogen plasma-metal reaction.[4, 7] In this present work, calcium oxide nanoparticles are synthesized by precipitation method and it is characterized by various techniques

2. Experimental Procedure

Calcium oxide nanoparticles were prepared by precipitation method. Calcium hydroxide (6grams) weighted and taken in a 250 ml beaker. Meanwhile, 25 ml of ethylene glycol was taken in another beaker. Both the reagents are mixed together and stirred vigorously at the rate of 450 rpm. Then keep the beaker in rest to settle down for 5 hours. After 5 hours, a milk white colored precipitate was obtained. The components are admitted to the whirled process to separate the precipitate from the solution using centrifuge. Then the white precipitate was repeatedly washed with distilled water for more than 2 times to remove the unwanted impurities. The obtained white precipitate was transferred to petri dish and dried in oven for 24 hours. Finally, the dried powder was calcinated using muffle furnace at 750°C for 3hours to obtain the white colored calcium oxide Nano powder and it was further characterized by different studies.

3. Results and discussions

3.1 X-ray diffraction analysis

The crystallographic composition of CaO nanoparticles synthesized by precipitation method was investigated in the Fig.1. The sharp peaks in the XRD exhibit the crystalline nature of calcium oxide nanoparticles. The XRD patterns of calcium oxide have a good match with (JCPDS card NO. 99-0070). The intense peaks appeared at 2°=29.5°, 37.5°, 54.0° were assigned to (111), (200) and (311) planes. The average size of particles in the prepared sample was determined the Debye's Scherrer formula. Then, the average crystallite size of CaO nanoparticles was found to be 19nm.

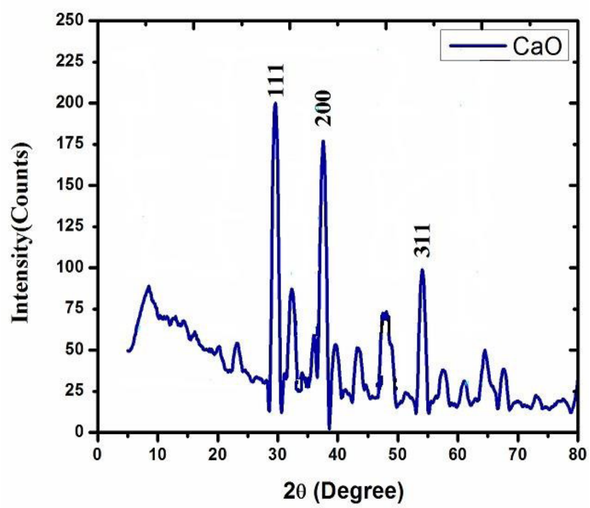

Fig. 1: XRD pattern of CaO nanoparticles

3.2 Scanning Electron Microscope (SEM) analysis

The surface morphology and nanostructures of CaO synthesized by precipitation method were characterized by SEM. The SEM micrograph illustrates the agglomerated form of CaO. The bright areas in this picture reveal the high emission of secondary electron. The SEM image of CaO nanoparticles at different resolutions are shown in the figure (3.2.1). It clearly reveals the obtained CaO nanoparticles have hexagonal morphology in high resolution.[8].

3.3 Energy Dispersive X-Ray Spectroscopic analysis

EDAX technique is used to analyze the elemental composition of the specimen through examining the peaks on the spectrum. The spectrum concludes the elemental percentages of the CaO nanoparticles. There are two peaks observed from EDAX spectrum: strong peak from the Oxygen atom (57.38%) along with the calcium atom (48.62%). There are no extra peaks which confirm no other elements or impurities.

3.4 FTIR Analysis

FTIR spectroscopy is an analytical technique used to identify the functional group present in the molecules. Additionally, the unique absorption bands can establish the characteristics of compounds The FTIR-spectra observed in

Table 1: Structural properties of CaO nanoparticles

2θ (deg)	D Spacing (Å)	FWHM (deg)	Crystallite Size (D) nm	Micro strain (ε)×10^{-1}m	Dislocation Density (δ)×10^{-15}m
29.5689	3.01861	0.45670	18.790	1.9267	2.8322
37.5250	2.39487	0.45000	19.473	1.8591	2.6703
54.0362	1.69568	0.47890	19.448	1.8615	2.6438

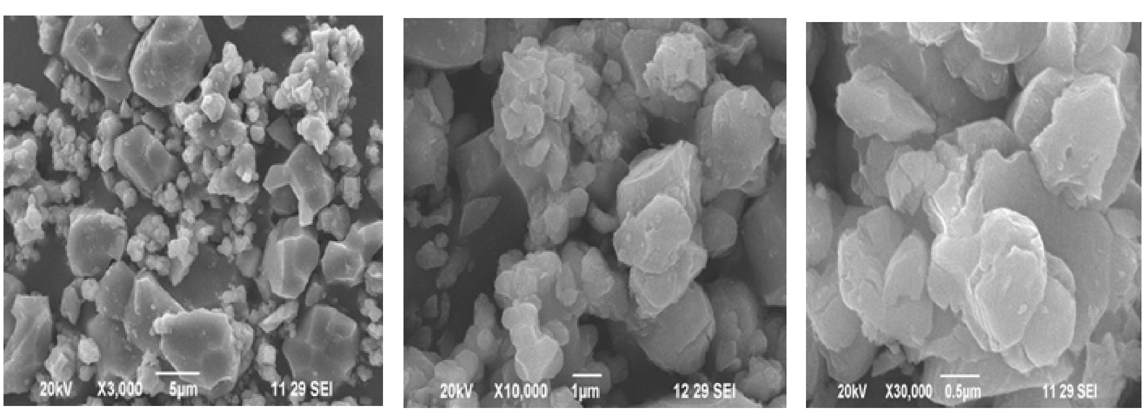

Fig. 2.1: SEM images of CaO nanoparticles

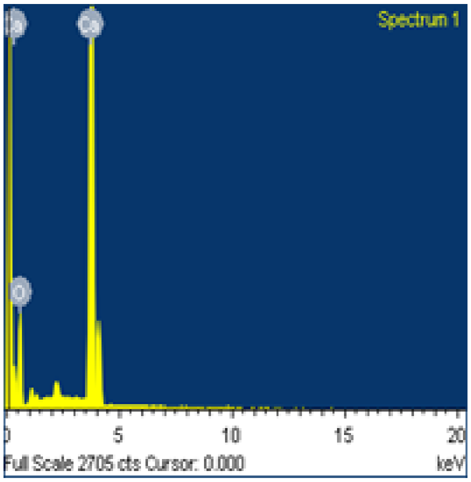

Fig. 2.2: EDAX Spectrum of CaO nanoparticles

Table 2: The calcium and oxide percentages of nanoparticles

Element	Weight %	Atomic%
Calcium	48.62	27.42
Oxide	57.38	72.58

the range of 400 to 4000 cm^{-1}. The peaks observed at 3643.53 cm^{-} 1, 2985.81 cm^{-1}, 2357.01cm^{-1},1803.44cm^{-1} indicate the presence of O-H, C-H, O=C=O, C=O stretching. The peaks observed at 875.68cm^{-1} and 707.88 cm^{-1} were assigned to Ca-O stretching.[9]

3.5 UV analysis

The optical properties of the synthesized calcium oxide nanoparticles are characterized by UV-Vis spectrum. The atoms and molecules absorb UV-Vis radiation and the electrons excited from lower to higher energy level. This UV-Vis spectrum observed in the range of (257-945nm). The band gap energy of the prepared nano sized CaO was calculated

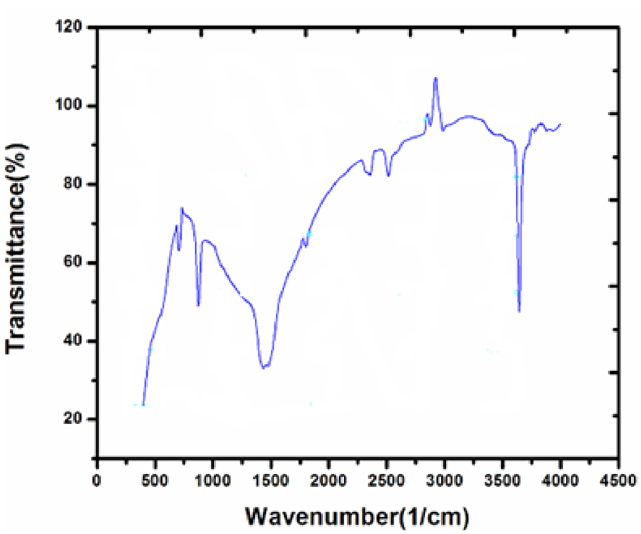

Fig.3: FTIR spectrum of CaO nanoparticles

Table 3: The functional groups of calcium oxide nanoparticles

Band Assignments	Wave Number (cm^{-1})	Appearance	Compound Class
O-H stretching	3643.53	Medium, sharp	Alcohol
C-H stretching	2985.81	medium	Alkane
O=C=O stretching	2357.01	Strong	Carbon-di-oxide
C=O stretching	1803.44	Strong	anhydride
O-H bending	1433.11	medium	alcohol
Ca-O stretching	875.68	strong	Calcium oxide
Ca-O stretching	707.88	strong	Calcium oxide

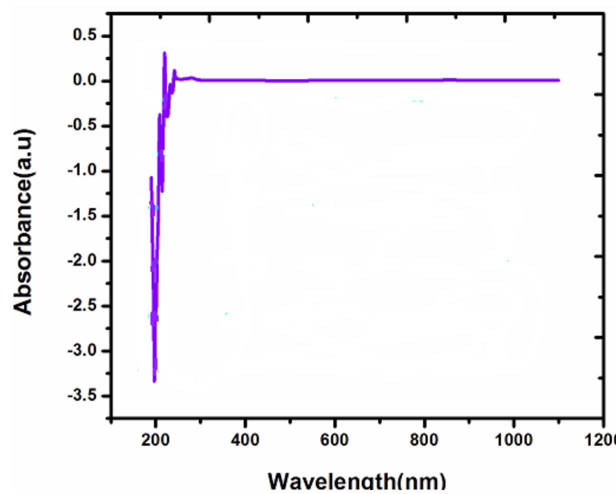

Fig. 4: Absorption spectra of CaO nanoparticles

Table 4: The band gap energy of the Nano sized Calcium Oxide

Sample	Wavelength(nm)	Band gap(eV)
CaO	257.00	4.8249

using Planck's equation. The determined band gap energy of the synthesized CaO nanoparticles was found to be 4.824eV. The graph is plotted across absorbance and wavelength of Nano sized calcium oxide is shown in the figure.[10]

3.6 Antibacterial Activity:

The antimicrobial activity of Calcium Oxide nanoparticles was studied using well diffusion method. Liquid Mueller Hinton agar media and the Petri plates were sterilized by autoclaving at 121° C for about 30 minutes at 15 lbs pressure. Under aseptic conditions in the laminar airflow chamber, about 20ml of the agar medium was dispensed into each Petri plate to yield a uniform depth of 4mm. After solidification of

Table 5: Results of antibacterial activities of CaO nanoparticles.

S. No	Microorganisms	Zone of inhibition in Diameter (mm)			Std. Antibiotic (Erythromycin 30 meg/disc)
		Contro l (100µl)	Sample name		
			50 µl	100 µl	
1	Bacillus cereus	–	12	20	28
2	Staphylococcus aureus	–	10	11	29
3	Escherichia coli	–	10	12	27
4	Klebsiella pneumoniae	–	–	10	27

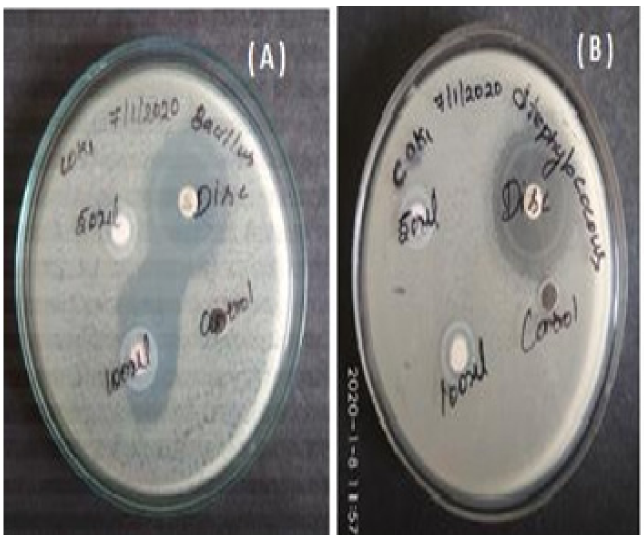

Fig 5A and B: (a) Zone of inhibition of CaO nanoparticles against Gram Positive bacteria such as (A) Bacillus and (B) Staphylococcus.

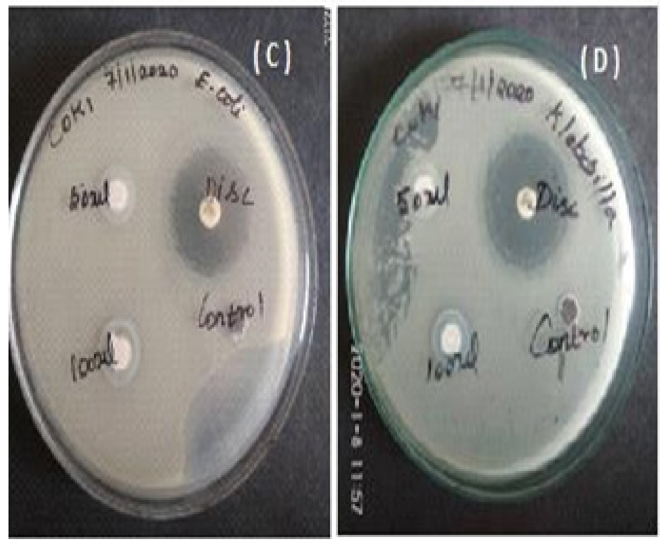

Fig. 5 (C and D: Zone of inhibition of CaO nanoparticles against Gram Negative bacteria as (C) E. coli and (D) Klebsilla

the media, 18 hrs culture of Gram positive microorganisms such as Bacillus cereus (MTCC 430), Staphylococcus aureus (MTCC 3160), Gram negative microorganisms such as E.coli (MTCC 1698) and Klebsiella pneumoniae (MTCC10309) obtained from IMTECH, Chandigarh were swabbed on the surface of the agar plates. Well was prepared by using cork borer followed with loading of 50 µl and 100 µl of each sample to the distinct well with sterile distilled water as negative control and gentamycin(30mcg/disc) as positive control. The sample loaded plates were then incubated at 37°C for 24 hours to observe the zone of inhibition.[9]

The disk diffusion agar method tests the effectiveness of antibiotics on specific microorganisms. In this present investigation the synthesized calcium oxide nanoparticles shows the antibacterial activity against certain gram positive and gram-negative bacteria which was regarded as human pathogenic microorganism. Table 5.1.1 shows the results of antibacterial activities of CaO can kill the bacteria's like Bacillus cereus, Staphylococcus aureus, Escherichia coli, Klebsiella pneumoniae at the certain amount of zone of inhibition of 50µl and 100 µl. The CaO nanoparticles acquires zero for the bacteria Klebsiella Pneumonia of 50µl. Therefore, we can conclude that the CaO nanoparticles have an average performance of antibacterial activity.

4. Conclusion:

In this present work, CaO nanoparticles were obtained by simple and cost-effective precipitation method. The XRD spectrum reveals the crystallite size of CaO as 19nm. The SEM image displays the hexagonal morphology of CaO nanoparticles. FTIR analysis confirms the presence of O-H, C=O, Ca-O, O=C=O stretching. In UV-Vis analysis the band gap energy of CaO nanoparticles were calculated and it was found to be 4.824 eV. EDAX confirms the elemental composition of CaO nanoparticles and the antibacterial study of synthesized CaO shows its sensitivity to both gram positive and gram-negative bacteria

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