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FACILE PLANT EXTRACT MEDIATED ECO-BENEVOLENT SYNTHESIS AND RECENT APPLICATIONS OF CAO-NPS:ASTATE-OF-THE-ART REVIEW

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ABSTRACT: Calcium oxide nanoparticles (CaO-NPs) have gained attention because of their low cost, stability, and wide range of applications. Plant extract-mediated synthesis is a simple, eco-friendly, and cost-effective method that uses natural plant compounds to produce nanoparticles. This review focuses on the synthesis, characterization, properties, and recent applications of plant-mediated CaO-NPs. Their uses in antimicrobial activity, catalysis, environmental remediation, dye degradation, biodiesel production, and biomedical applications are discussed. The review also highlights the advantages and challenges of this green synthesis approach and its potential for sustainable nanotechnology.

Keywords: *Calcium oxide nanoparticles; Plant extract; Green synthesis; Eco-friendly synthesis; Nanotechnology; Antimicrobial activity; Environmental applications.*

1. INTRODUCTION

Nanotechnology is currently a large topic that covers various scientific and technological industries, providing unique potential in medicine, renewable energy, and healthcare. Nanoparticles (NPs) range in size from 1 to 100 nanometers. As a result, their chemical and biological properties are vastly different. Nanoparticles outperform bigger materials due to their small size, angular shape, extraordinary stability, and inclination for dispersion. Furthermore, the greater surface area to volume ratio of nanoparticles (NPs) is significant since it boosts their biological and catalytic activity significantly. Nanoparticles (NPs) have a variety of applications, including agriculture, health, electronics, water purification, and catalysis. Nanoparticles have a variety of other properties in addition to their durability, charge capacity, melting temperature, and strength when separated. In recent years, the use of "green nanotechnology" has increased significantly across various industries. The integrity of these sectors improves as more nanotechnology is included into their operations.

CaO is a chemical compound composed of oxygen and an alkaline earth metal. This material restricts the transmission of electricity due to its high energy requirements, broad band gap of 7.1 eV, and high dielectric constant of 11.8. Calcium oxide nanoparticles, or CaO-NPs, are a widely available, low-cost, and simple basic material that can be used for heterogeneous catalysis in a variety of chemical reactions. These nanoparticles are safe to use and have numerous applications. CaO-NPs can be used to absorb CO_2, remove Cr(VI), and speed the transesterification of palm and sunflower oil, in addition to being photocatalysts, adsorbents, bio-ceramics, and biodiesel production aids. Furthermore, they have the potential to remove additional dangerous metal ions. CaO-NPs are also important in photothermal therapy, photodynamic therapy, drug delivery, tissue degradation, and chemotherapeutic drug transfer between synapses. As a result, significant changes have been made to antibacterial and antifungal medications. Their consistent and efficient application in biology makes this

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possible.
There are now several generally accepted techniques for the simple synthesis of CaO-NPs. Solution combustion flame-assisted synthesis, co-precipitation, sonication, ball-milling, thermal breakdown, and the sol-gel method are examples of these. In contrast, the technologies described above are quite advantageous. On the other side, they are expensive, time-consuming and difficult to operate, use a lot of energy, have complicated processes, and produce undesired byproducts. As a result, it is critical that we address the concerns as soon as possible and develop "green nanotechnology" as a means of establishing a safer, more cost-effective, and environmentally sustainable alternative. As a result of its safety, cost-effectiveness, and lack of dangerous chemical components, the manufacturing of nanoparticles from plant extract has received widespread acceptance. By using natural capping and reducing agents, CaO-NPs can be synthesized more efficiently using plant extract-mediated nanoparticles (NPs).
The functionality of CaO-NPs generated from plant materials, their characterisation, and prospective innovative applications were the primary emphasis of this review.

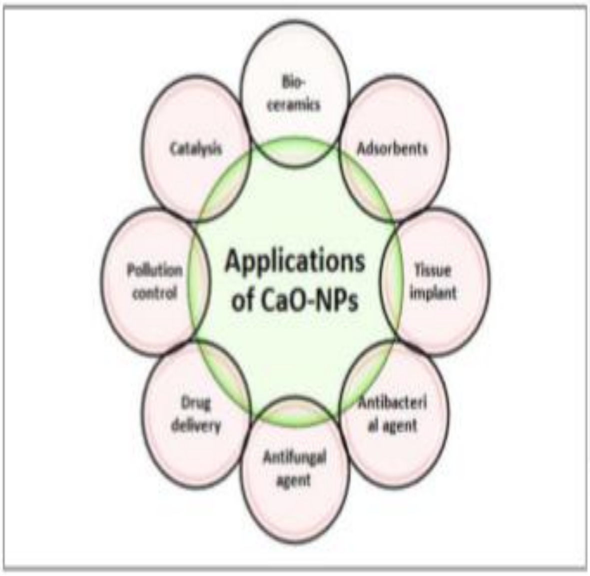

Figure 1.Calcium oxide nanoparticles have numerous practical applications.

Scope Of This Review:

Despite a few anecdotal examples, no extensive examination into the possible applications of plant-based CaO-NPs has been conducted. The medicinal and catalytic applications of CaO-NPs are discussed in this review. After describing the CaO-NPs synthesis process, the particles were thoroughly examined using XRD, other spectroscopic techniques, and microscopic approaches. An in-depth analysis of the time-tested techniques for manufacturing CaO-NPs from plant extracts, as well as the many applications for which they can be used, could aid researchers in nanotechnology, agriculture, biomedicine, and environmental remediation.

plant material assisted eco-benignsynthesisofcao-nps:

Because of their constant nature and environmental safety, extracts obtained from diverse plant components (e.g., stems, roots, bulbs, foliage, flowers, or fruits) are preferred over alternative biomaterials when making metal oxide nanoparticles. Biomolecules in the plant

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broth, such as proteins, amino acids, vitamins, polysaccharides, enzymes, and flavonoids, produce the required nanoparticles.

Plant extract-mediated biosynthesis has various advantages (Figure 2), including plant safety, low cost, user-friendliness, quick production, and environmental friendliness. Numerous studies have been conducted to investigate the ability of various plant species to synthesize CaO-NPs, as shown in Table 1. Because the procedure offers several benefits.

CaO-NPs can be synthesized from a plant's stem, leaves, and spores. The water-soluble phytochemical components are principally responsible for CaO-NPs' stability. CaO-NPs must be evaluated using a number of complicated techniques after they have been manufactured in a laboratory.

Figure 2. Metal oxide nanoparticle production is significant.

2. METHODOLOGY FOR PLANT MEDIATED GREENSYNTHESISOF CAO-NPS

Various plant parts, including fruits, foliage, and roots, are rinsed with distilled water to create CaO-NPs using the plant extract method. After chopping them with a household mixer, they are reduced to an aqueous bouillon by boiling them in double-distilled water.

Table 1. CaO-NPs, or calcium oxide nanoparticles, are made from several plant sources. These can take on a variety of shapes and forms.

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Entry	Name of Plants	Part	Precursors	Shape	Size (nm)	Reference
1	*Azadirechta indica*	Leaves	$Ca(NO_3)_2$	Star shaped	50-200	[42]
2	*Broccoli*	Leaves	$CaCl_2$	Cube, Spherical, Hexagonal	32-45	[36]
3	*Cissus quadrangularis*	Stem	$CaCl_2$	Hexagonal	58	[57]
4	*Cissus quadrangularis*	Leaves	Egg shell	-	-	[58]
5	*Acalypha indica*	Leaves	Egg shell	-	-	[58]
6	*Solanum nigrum*	Leaves	Egg shell	-	-	[58]
7	*Phyllanthus niruri*	Leaves	Egg shell	-	-	[58]
8	*Hylocereus polyrhizus*	Fruits	$CaCl_2.2H_2O$	Rod	18.98	[43]
9	*Mentha piperata*	Leaves	$CaCl_2$	Disc	-	[59]
10	*Oscimum Sanctum*	Leaves	Egg shell	-	40-70	[60]
11	*Rhododendron arboreun*	Leaves	$Ca(NO_3)_2$	Broad needle like shape	-	[61]
12	*Papaya*	Leaves	$Ca(NO_3)_2.4H_2O$	Agglomerated	86-117	[62]
13	*Tea*	Leaves	$Ca(NO_3)_2.4H_2O$	Agglomerated	89-180	[62]

Filtration and centrifugation are two further methods for purifying plant broth. CaO-NPs can be created by varying the temperature, pH, egg shell powder-to-plant water ratio, and time between processes. The plant broth rapidly mixes with solutions containing egg shell powder or calcium metal compounds in different quantities at room temperature. This method rapidly manufactures CaO-NPs in an environmentally benign, sustainable, and practical manner. The use of dangerous external compounds for capping or stabilizing is unnecessary because the plant broth is rich in phytochemicals that act as natural stabilizers and reducers. The authors describe how to use broccoli leaf extract in the biogenic synthesis of CaO-NPs. Finally, the NPs can be isolated by rapidly rotating them and then thoroughly washing them in water or a suitable solvent. CaO-NPs were then cooked to a high temperature in a muffle furnace using a clay crucible. Calcium oxide nanoparticles (CaO-NPs) are processed and collected in powder form for future research and use.

3. CHARACTERIZATIONTECHNIQUESFORCAO-NPS

Following their biological creation, it is necessary to provide a description of the CaO-NPs. Dimensions, uniformity, shape, durability, and chemical composition are all characteristics of CaO-NPs. Each of these CaO-NPs features is important in a variety of situations. Several widely used procedures are used to determine and evaluate the properties of CaO-NPs. Among these techniques are powder X-ray diffraction (XRD), energy-dispersive spectroscopy (EDS), transmission electron microscopy (TEM), and Fourier transform infrared spectroscopy (FTIR).

UV-visible spectroscopy is a commonly used method. This method makes use of light with wavelengths ranging from 200 to 800 nanometers. The composition of the CaO-NPs was established by evaluating spectrophotometric absorption readings between 400-450 nm and 260-410 nm. The surface plasmon resonance of the CaO-NPs produced from Cissusquadrangularis is responsible for the UV-visible band peak detected at 400-450 nm. The XRD pattern (Figure 3) was used to investigate the CaO-NPs' structure, crystal planes, and average particle size. The strong and narrow diffraction spots suggest that the CaO-NPs have crystallized. The average size of the CaO-NPs was measured by looking at the broadening of the diffraction peaks associated with the strongest reflections on JCPDS (Joint Committee on Powder Diffraction Standards) standard cards. Scherrer's equation (Equation 1) was applied to the XRD diffraction pattern to determine the crystallite size of the CaO-NPs.

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$$d = K\lambda / \beta COS\theta \quad (1)$$

What is the exact location?

The length of an X-ray wave is indicated by, while the size of a crystallite is generally d nanometers.

The Scherrer constant, written as K, is widely assumed to be 0.94.

The full width at half maximum (FWHM) of is represented as radians.

The Bragg angle, or is important to Bragg's rule.

The scanning electron microscopy (SEM) scan revealed accurate information about the average size and morphology of the generated CaO-NPs (Figure 3). EDX spectroscopy is frequently used to determine the chemical composition of biosynthesized CaO-NPs (Figure 4). TEM, or transmission electron microscopy, is the method used to investigate the precise size and shape distribution of CaO-NPs. The physical and functional properties of nanoparticles (NPs) can be investigated using FTIR spectroscopy. This method is used to determine the degree of chemical connection between metal atoms on the surface of NPs and plant extract. The biomolecules contained in plant water extracts that serve to encapsulate and support CaO-NPs during their biogenesis process were identified using FTIR spectroscopic methods. Experts have used more significant approaches to describe metal oxide nanoparticles, as shown in Figure 5.

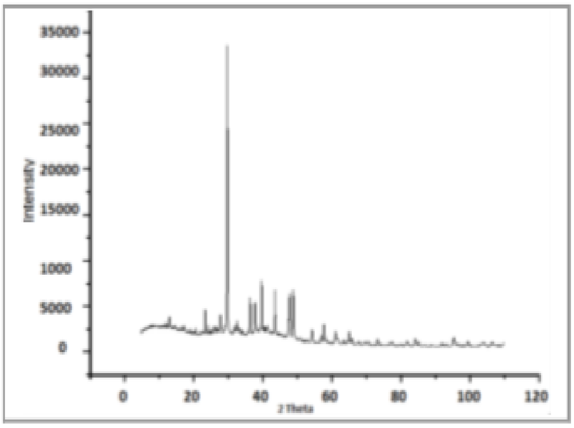

Figure 3.Figure 61 depicts the X-ray diffraction (XRD) pattern of biologically produced calcium oxide nanoparticles (CaO-NPs).

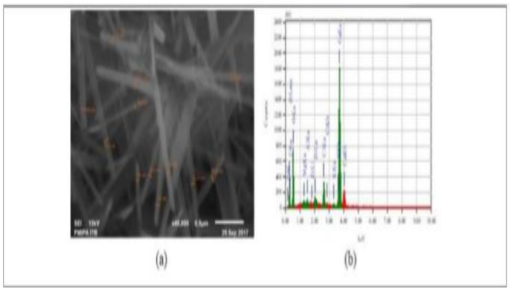

Figure 4.Figure 43 depicts the energy-dispersive X-ray (EDX) curve and scanning electron microscopy (SEM) picture of biologically produced calcium oxide nanoparticles (CaO-NPs).

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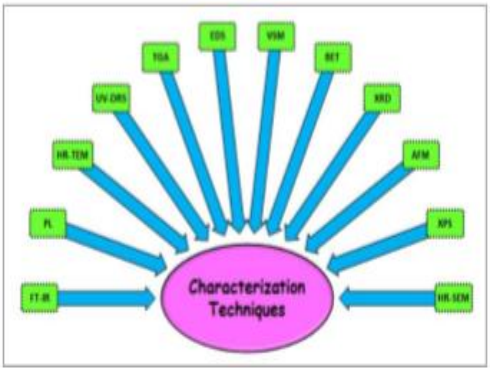
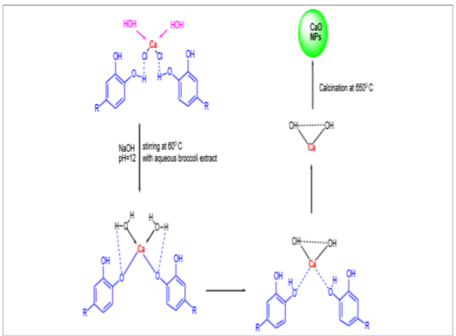


Figure 5.There are several ways to talk about nanoparticles.

Proposed Mechanism ForCao-NpsFormationUsingPlantExtract

Phytoconstituents such as anthocyanins, flavonoids, coumarins, saponins, phenols, amino acids, steroids, and sugars are required for the production of nanoparticles (NPs). Metal oxide nanoparticles are manufactured using a variety of plant components. Plant extract synthesis is greatly influenced by phytochemicals. CaO-NPs were created by Onwudiwe et al. using a material obtained from broccoli leaves. According to his research findings, the flavonoid component, such as

The leaf extract contains quercetin, which acts as a stabilizer and a diuretic. When the aromatic hydroxyl groups of quercetin combine with calcium metal ions, a stable dyad is produced. His explanation of the CaO-NPs production process (Scheme 1) was basic and uncomplicated.



Scheme 1.The use of a byproduct of broccoli leaves in the manufacture of calcium oxide nanoparticles (CaO-NPs) appears reasonable.

4. APPLICATIONSOFBIOGENICALLYSYNTHESIZEDCAO-NPS

Owing to their unique features and properties, CaO-NPs are widely used in several fields, including photocatalysis, antioxidant activity, bacterial eradication, and cancer therapy. Biogenically synthesized CaO-NPs are particularly valuable for medical applications, especially for microbial elimination.

Table 2 summarizes the photocatalytic and antimicrobial applications of biogenically synthesized CaO-NPs. Prashantha et al. synthesized CaO-NPs and evaluated their activity against *Bacillus* bacteria using an extract obtained from the leaves of *Azadirachta indica*.

Onwudiwe et al. used an extract obtained from broccoli leaves to synthesize calcium oxide nanoparticles (CaO-NPs). They investigated the photocatalytic properties of the synthesized

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nanoparticles. The CaO-NPs ranged in size from 32 to 45 nm and exhibited different morphologies, including cubic, spherical, and hexagonal shapes. The researchers evaluated the degradation of bromocresol green dye. A degradation efficiency of 57.63% was achieved when CaO-NPs were used as a photocatalyst under UV-light irradiation.

Ayyasami et al. reported that the use of *Cissus quadrangularis* stem extract for the synthesis of CaO-NPs was environmentally friendly. They also investigated the potential antibacterial properties of the synthesized nanoparticles. The CaO-NPs were approximately 58 nm in diameter. The nanoparticles showed strong antibacterial activity against *Salmonella typhi, Escherichia coli, Klebsiella pneumoniae, Pseudomonas aeruginosa, Vibrio cholerae*, and *Staphylococcus aureus*.

According to Pasupathi et al., CaO-NPs can be synthesized using leaf extracts of *Phyllanthus niruri, Acalypha indica, Solanum nigrum*, and *Cissus quadrangularis*. The agar well diffusion method was employed to evaluate the antibacterial efficiency of these nanoparticles against *Bacillus subtilis, Staphylococcus aureus*, and *Escherichia coli*.

Ramli et al. synthesized rod-shaped CaO-NPs using fruit samples of *Hylocereus polyrhizus*. Turbidimetry was used to evaluate the effectiveness of different concentrations of these nanoparticles against *Candida albicans*.

Mirza et al. reported the synthesis of antibacterial, disk-shaped CaO-NPs using an extract of *Mentha piperita* leaves. Gurav et al. reported a method for synthesizing calcium oxide nanoparticles (CaO-NPs) using an extract prepared from *Ocimum sanctum* leaves. The researchers also reported the antimicrobial properties of the synthesized nanoparticles, which ranged in size from 40 to 70 nm.

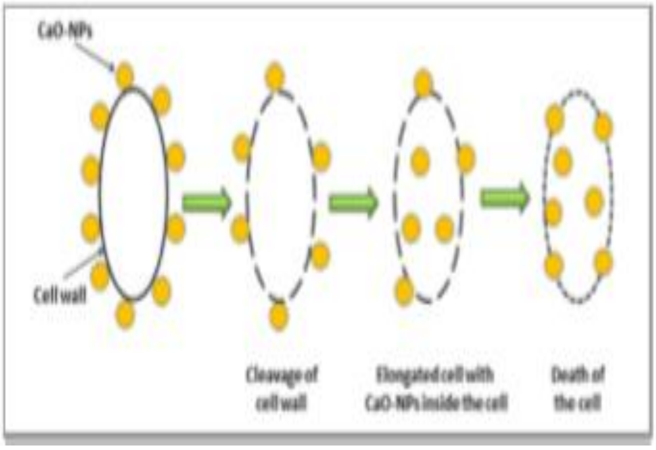

Figure 5. The most plausible method by which CaO-NPs destroy infections.

Joshi et al. investigated the biogenic synthesis of CaO-NPs using a substance isolated from the leaves of Rhododendron arboreum. They also looked into the effectiveness of CaO-NPs in destroying bacteria. According to the study, CaO-NPs had remarkable bactericidal action against Proteus vulgaris, Streptococcus mutans, and Escherichia coli. George and his colleagues used a mixture of tea leaves and pineapple to depict the green color of CaO-NPs. The researchers also tested the CaO-NPs for their ability to eliminate bacteria and function as a photocatalyst. The CaO-NPs produced via biosynthesis ranged in size from 86 to 148 nanometers. The photocatalytic study shows that the biosynthesized CaO-NPs are effective at

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degrading the Congo red pigment. The antibacterial investigations indicate that CaO-NPs have the potential to be used in the food packaging business. This is because CaO-NPs have been shown to effectively interact with the cell membrane, consequently suppressing bacterial action (Figure 5).

Table 2 CaO-NPs generated from various plant sources have numerous applications.

Entry	Name of Plants	Applications	References
1	*Azadirechta indica*	Antimicrobial activity	[42]
2	*Broccoli*	Photocatalytic activity	[36]
3	*Cissus quadrangularis*	Antibacterial activity	[57]
4	*Cissus quadrangularis*	Antibacterial activity	[58]
5	*Acalypha indica*	Antibacterial activity	[58]
6	*Solanum nigrum*	Antibacterial activity	[58]
7	*Phyllanthus niruri*	Antibacterial activity	[58]
8	*Hylocereus polyrhizus*	Antifungal activity	[43]
9	*Mentha piperata*	Antibacterial activity	[59]
10	*Oscimum Sanctum*	Antimicrobial activity	[60]
11	*Rhododendron arboreun*	Antimicrobial activity	[61]
12	*Papaya*	Antibacterial and photocatalytic activity	[62]
13	*Tea*	Antibacterial and photocatalytic activity	[62]

FutureProspects

- The utilization of plant extracts to produce varied amounts of calcium oxide nanoparticles is a quick and environmentally safe method. This approach is well-known and useful in a variety of situations. Several CaO-NPs have been produced using a variety of plant species. Nonetheless, some research areas still demand attention. Some instances are as follows:
- The lack of precise stoichiometric ratios of precursors and plant extracts hampers understanding the product's synthesis and achieving precise control over its structure.
- The specific process by which the plant extract is used in CaO-NP production is unknown.
- A thorough investigation of the used plants or plant materials is required for a detailed understanding of the working mechanisms.
- It has been established that certain plant species can naturally manufacture calcium oxide nanoparticles (CaO-NPs). As a result, the manufacture of CaO-NPs necessitates the utilization of a large number of medicinal plants.
- Green CaO-NPs created have a wide range of applications, including pharmaceutical conveyance, biosensor creation, agricultural help, and hydrogen production.

5. CONCLUSION

This study looks into the recent rise in interest in making CaO-NPs from diverse plant parts in a simple way, which has applications in a range of disciplines.

The catalyst has the potential to be used as a bio-ceramics adsorbent for medication delivery, tissue dissolution, and pollutant emission reduction. To generate nanoparticles using living organisms, innovative, cost-effective, and environmentally sustainable technologies have been developed, as compared to archaic, toxic, and more complex chemical and physical procedures. CaO-NPs are still used for environmental stabilization; consequently, fresh approaches are needed to define them and select suitable plant species so that the goal can be

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reached while preserving plant variety.

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