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PLANT-MEDIATED ECO-FRIENDLY SYNTHESIS AND APPLICATIONS OF CAO-NPS

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ABSTRACT: The development of more reliable and long-lasting methods for producing nanoparticles (NPs) is a cornerstone of environmentally friendly nanotechnology. The conventional method of producing nanoparticles is fraught with difficulty, costly, and potentially harmful to human and environmental health. In order to circumvent these risks, researchers synthesized biopolymers derived from plants, fungus, and bacteria into calcium oxide nanoparticles (CaO-NPs). Reaction conditions have a significant impact on CaO-NPs' size, function, and form. Additionally, environmentally benign synthesis of CaO nanoparticles is within the realm of possibility. Producing biofuels, incorporating refractory materials, removing Cr(VI), adsorbing pollutants, eliminating microbes, and transesterifying oil are just a few of the many promising uses for this. Several plant species and their components used to make CaO-NPs were examined by the researchers in this work. The method of production, functioning, description, and pure production were among the many CaO-NP themes discussed in the book. They claimed to be still running.

***Keywords*:** Green nanotechnology; Plant extracts; CaO-NPs; Mechanism; Applications

1. INTRODUCTION

Nanotechnology encompasses a wide range of scientific and technological fields. It has a lot of promise for use in alternative energy, healthcare, and medicine. Nanoparticles (NPs) range in size from one hundred nanometers to one thousand. This results in very distinct chemical and biological characteristics between the two. Because of their small size, angular shape, increased stability, and propensity to disperse, nanoparticles outperform larger materials in terms of efficacy. To greatly enhance their biological and catalytic activity, nanoparticles (NPs) must have a high surface area to volume ratio. Among the many fields that make use of nanoparticles (NPs) are electronics, medicine, agriculture, and catalysis. In addition to their melting point, charge capacity, endurance, and strength, nanoparticles display a long list of auxiliary qualities. The use of "green nanotechnology" has exploded in recent years, touching numerous industries. The more these companies use nanotechnology, the more credible they seem.

The reaction of an alkaline earth metal with oxygen produces the chemical compound CaO. Because of its high energy requirements, wide band gap, and higher dielectric constant of 11.8 eV, this material blocks the flow of electricity. For a number of chemical reactions involving heterogeneous catalysis, calcium oxide nanoparticles (CaO-NPs) are an easily available, cost-effective, and practical material. These nanoparticles have several potential uses and are completely safe to use. In addition to removing chromium(VI) and sequestering carbon dioxide, calcium oxide nanoparticles (CaO-NPs) can speed up the transesterification process of sunflower and palm oils. In addition to their potential use as photocatalysts, adsorbents, bio-ceramics, and biodiesel generators, they may have other potential uses. In addition, they could be able to get rid of other harmful metal ions. Photodynamic therapy,

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photothermal therapy, tissue deterioration, and the delivery of chemotherapeutic drugs across synapses all rely on calcium oxide nanoparticles (CaO-NPs). This has led to major shifts in the design of antimicrobial and antifungal medications. They are able to accomplish this because they are reliable and efficient in the field of biology.

The simple synthesis of CaO nanoparticles can be accomplished using a number of well-established methods. Thermal decomposition, sol-gel, ball milling, sonication, co-precipitation, and solution combustion flame-assisted synthesis are some of the approaches. Having said that, those technologies are really helpful. However, they demand a lot of effort, are difficult to maintain, and cost a pretty penny. In addition, they necessitate intricate procedures, consume a great deal of energy, and result in harmful waste. Therefore, we must act quickly to resolve the issues and promote "green nanotechnology" as a safer, more environmentally friendly, and cost-effective substitute. Because they are non-toxic, inexpensive, and safe, nanoparticles synthesized from plant extracts have attracted a lot of interest. Incorporating plant extracts into nanoparticles (NPs) can improve the production of CaO-NPs by making use of natural reducing and capping agents.

This review mainly aimed to cover the features, efficacy, and potential novel uses of CaO nanoparticles generated from plants.

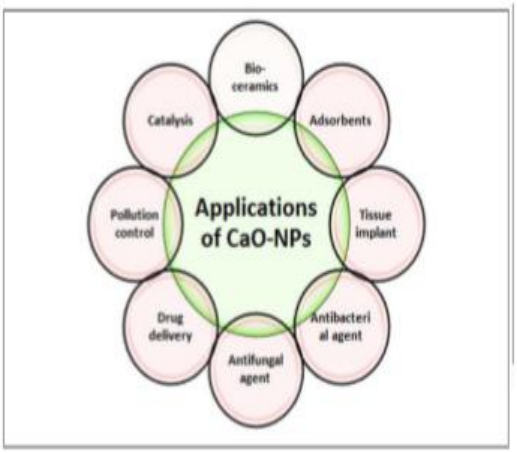

Figure 1.Calcium oxide nanoparticles have numerous practical applications.

Scope Of This Review:

The potential uses of plant-based CaO-NPs have not been investigated in depth, despite multiple anecdotal cases. This article takes a look at the potential catalytic and medicinal applications of CaO nanoparticles. The particles were thoroughly analyzed using XRD, other spectroscopic methods, and microscopic techniques after the CaO-NPs preparation process was described. Researchers in the fields of biomedicine, agriculture, nanotechnology, and environmental remediation can benefit from a thorough examination of the numerous uses of established methods for producing CaO nanoparticles from plant extracts.

Plant material assisted eco-benign synthesis of cao-nps:

The environmentally safe production of metal oxide nanoparticles is accomplished by employing extracts from a variety of plant parts, including stems, roots, bulbs, foliage, flowers, and fruits, as opposed to other biomaterials. The necessary nanoparticles are synthesized by biomolecules present in plant fluid, such as flavonoids, vitamins, polysaccharides, enzymes, and amino acids.

Figure 2 outlines the several advantages of plant-extract mediated biosynthesis, including its simplicity, low cost, ecological sustainability, and plant-safety. The efficiency of several

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plant species in the synthesis of CaO-NPs has been the subject of multiple investigations, as shown in Table 1. since the technique has numerous advantages.

The plant's stem, leaves, and spores can be used to create CaO nanoparticles. Because they contain water-soluble phytochemical components, CaO nanoparticles are stable. After being synthesized in a lab, CaO nanoparticles must pass a battery of rigorous tests.



Figure 2.Metal oxide nanoparticle production is significant.

2. METHODOLOGY FOR PLANT MEDIATED GREENSYNTHESIS OF CAO-NPS

Fruits, leaves, and roots are just a few of the plant components that can be washed with distilled water to yield CaO nanoparticles using the plant extract method. To make an aqueous bouillon, the ingredients are first minced in a home mixer and then cooked in water that has been double-distilled.

Table 1. Calcium oxide nanoparticles, or CaO-NPs, are derived from a variety of plants. These can have many different forms and shapes.

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 other methods for purifying plant broth. In order to create CaO nanoparticles, one can manipulate the following variables: temperature, pH, eggshell powder to plant water ratio, and processing time intervals. Various solutions containing calcium metal compounds or eggshell powder quickly amalgamate with the plant broth when it is at room temperature. This method produces CaO nanoparticles in a way that is beneficial, resilient, and sustainable for the environment. Because of the high concentration of phytochemicals in the plant broth, which act as natural reducers and stabilizers, no toxic ingredients are required to cap or stabilize the mixture. By utilizing broccoli leaf extract, the authors shed light on the biogenic synthesis of CaO nanoparticles. Isolating the nanoparticles requires a quick spin in the centrifuge followed by a thorough washing in water or a suitable

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solvent. The next step was to heat the CaO nanoparticles in a muffle furnace with a clay crucible. Powdered calcium oxide nanoparticles (CaO-NPs) are prepared for further research and potential uses by treating and storing them.

3. CHARACTERIZATION TECHNIQUES FOR CAO-NPS

The CaO-NPs that are formed physiologically need to be clarified. It is crucial that CaO nanoparticles meet certain criteria in terms of size, shape, homogeneity, lifespan, and chemical makeup. In different situations, each CaO-NP characteristic is crucial. Many time-honored methods have been developed for the purpose of evaluating and quantifying the properties of CaO-NPs. Some examples of these techniques are transmission electron microscopy (TEM), energy-dispersive spectroscopy (EDS), and particle X-ray diffraction (XRD).

Spectroscopy that uses both visible and ultraviolet light is one example. Light with a wavelength in the range of 200 to 800 nanometers is employed in this process. Spectrophotometric absorption measurements in the 260-410 nm and 400-450 nm wavelength ranges allowed us to determine the CaO nanoparticles' composition. In the ultraviolet-visible spectrum, the surface plasmon resonance of Cissus quadrangularis-derived CaO nanoparticles peaks between 400 and 450 nm. The XRD pattern was used to examine the structure, crystal planes, and average particle size of the CaO-NPs (Figure 3). The sharp, narrow diffraction patterns indicate that the CaO nanoparticles have solidified. The average size of the CaO nanoparticles was determined by looking at the broadening of the diffraction peaks on the JCPDS standard cards that correspond to the highest strong reflections. Applying Scherrer's equation (Equation 1) to the XRD diffraction pattern allowed us to determine the size of the CaO-NPs' crystallites.

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

What is the exact location?

The typical width of a crystallite is d nanometers, and the standard representation of an X-ray wave is.

K is the Scherrer constant, and 0.94 is a common value.

The FWHM, or full width at half maximum, of is represented using radians.

Bragg's angle is the foundation of Bragg's rule.

Scanning electron microscopy (SEM) was used to accurately evaluate the average dimensions and form of the produced CaO nanoparticles (Figure 3). Biosynthesized CaO nanoparticles can have their chemical composition determined via EDX spectroscopy, as shown in Figure 4. We use transmission electron microscopy (TEM) to examine the morphological distribution and precise dimensions of the CaO nanoparticles.

Nanoparticle (NP) physical and functional properties can be studied using FTIR spectroscopy, which is a prime example of such a method. Using this technique, we can measure how strongly the plant extract binds to the metal ions present on the nanoparticles' surfaces. The biomolecules in plant water extracts that aid and encase CaO nanoparticles during their formation were discovered using FTIR spectroscopic techniques. Figure 5 shows that experts have provided more detailed explanations of metal oxide nanoparticles.

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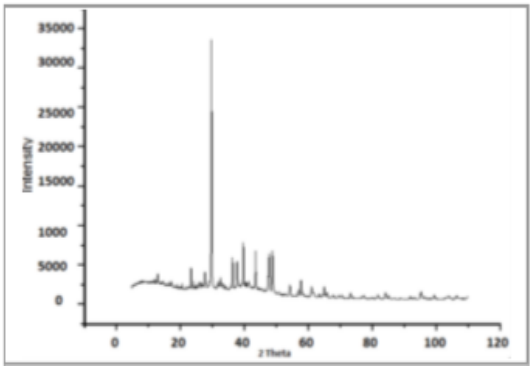

Figure 3. The X-ray diffraction (XRD) pattern of calcium oxide nanoparticles (CaO-NPs) that have been biologically produced.

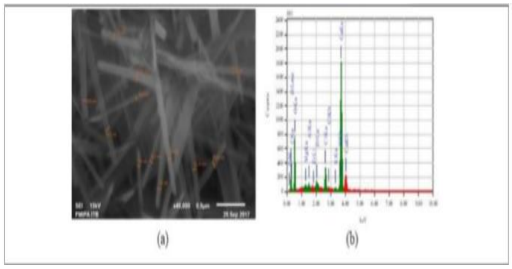

Figure 4. Biologically produced calcium oxide nanoparticles (CaO-NPs) are illustrated in Figure by the energy-dispersive X-ray (EDX) curve and scanning electron microscopy (SEM) image.

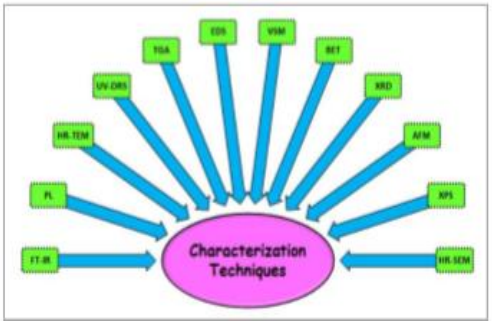

Figure 5. Nanoparticles can be examined by several methodologies..

Proposed Mechanism For Cao-Nps Formation Using Plant Extract

Nanoparticle (NP) production requires phytoconstituents like carbs, amino acids, phenols, coumarins, saponins, anthocyanins, and flavonoids. Nanoparticles of metal oxide are synthesized using a wide range of plant resources. Phytochemicals have a major impact on the extraction process. Onwudiwe et al. used a chemical that was found in broccoli leaves to make CaO nanoparticles. According to his findings, the flavonoid component includes

The diuretic and stabilizing properties of quercetin are found in the leaf extract. When quercetin's aromatic hydroxyl groups come into contact with calcium metal ions, a stable dyad is formed. The method for synthesizing CaO-NPs (Scheme 1) was well explained by him.

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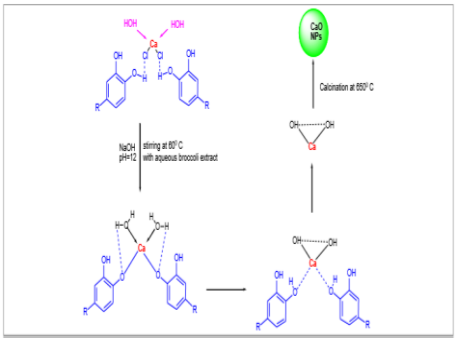

Figure 6. The utilization of a byproduct from broccoli leaves in the production of calcium oxide nanoparticles (CaO-NPs) seems justifiable.

4. APPLICATIONS OF BIO GENICALLY SYNTHESIZED CAO-NPS

The exceptional qualities and traits of calcium oxide nanoparticles (CaO-NPs) make them useful in many different areas. Photocatalysis, antioxidant activity, microbial elimination, cancer treatment, and others fall into this category. Biogenerated CaO nanoparticles have many potential medical applications, including the elimination of microbes.

All of the photocatalytic applications discussed in the book are listed in Table 2. Using a compound extracted from Azadirachta indica leaves, Prashantha et al. synthesized calcium oxide nanoparticles (CaO-NPs), which were subsequently tested against Bacillus bacteria. Using a byproduct of broccoli leaves, Onwudiwe et al. created calcium oxide nanoparticles (CaO-NPs). They then checked if the nanoparticles may make photocatalysis easier. With diameters ranging from 32 to 45 nm, CaO nanoparticles display a wide variety of shapes, including cubes, spheres, and hexagons. Scientists looked at how much the bromocresol green pigment deteriorated. By exposing CaO-NPs to UV light and using them as a photocatalyst, the amount could be reduced by 57.63%.

Environmental sustainability was found by Ayyasami et al. in the synthesis of CaO-NP from the stem extract of Cissus quadrangularis. Additionally, they investigated if the nanoparticles could kill bacteria. The size of the CaO nanoparticles is 58 nanometers. The growth of Salmonella typhi, Escherichia coli, Klebsiella pneumoniae, Pseudomonas aeruginosa, Vibrio cholera, and Staphylococcus aureus was significantly reduced by CaO-NPs, according to scientific studies.

Some plants, according to Pasupathi et al., can produce CaO nanoparticles on their own. These plants include Phyllanthus niruri, Acalypha indica, Solanum nigrum, and Cissus quadrangularis. The agar well diffusion method was used to evaluate the efficacy of these nanoparticles in eliminating infections caused by Staphylococcus aureus, Bacillus subtilis, and Escherichia coli. In their study, Ramli et al. created rod-shaped calcium oxide nanoparticles (CaO-NPs) using a fruit sample from Hylocereus polyrhizus. Using turbidimetry, the effectiveness of various concentrations of these nanoparticles against Candida albicans was evaluated.

An antibacterial disk-shaped CaO nanoparticle was subsequently identified by Mirza et al. after the leaves of Menthapiperita were isolated from a liquid solution. The process used to create calcium oxide nanoparticles (CaO-NPs) from a leaf extract of Oscimum sanctum was described in detail by Gurav et al. Nanoparticles with a size range of 40–70 nm were found by the experts to have antibacterial properties.

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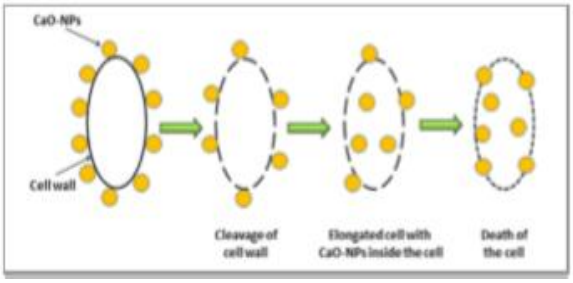

Figure 7 .The most plausible method by which CaO-NPs destroy infections.

Joshi and associates used a substance made from Rhododendron arboreum leaves to investigate the process by which living things produce CaO nanoparticles. To determine whether CaO-NPs were effective in killing bacteria, an experiment was carried out. The study proved that CaO-NPs were highly effective in killing E. coli, S. mutans, and P. vulgaris bacteria. By combining pineapple and tea leaves, George and his colleagues demonstrated the environmentally friendly nature of CaO-NPs.

The photocatalytic and antibacterial properties of CaO-NPs were investigated further through the course of additional research. The CaO nanoparticles that were formed by biosynthesis range in size from 86 to 148 nanometers. This range pertains to the size of the particles. The photocatalytic experiment revealed that the CaO-NPs that were biosynthesized are highly effective at destroying the Congo red pigment. This was determined by the findings of the experiment. Researchers have come to the conclusion that CaO-NPs have the potential to be utilized in the packaging of food goods due to the fact that they have been demonstrated to contain antibacterial capabilities. Because CaO-NPs are able to effectively cling to cell membranes, they are able to prevent the development of microorganisms (Figure 5). This is the reason why situations are the way they are.

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]

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Future Prospects

Nanoparticles of calcium oxide at different concentrations can be synthesized using plant extracts in an easy and environmentally friendly way. Many people are aware of and make use of this strategy. The production of various CaO nanoparticles has made use of a wide variety of plant species. However, further investigation is required in certain areas of research. Some instances are as follows:

- The inability to completely control the product's structure and comprehend its production process is caused by the absence of appropriate stoichiometric ratios for plant extracts and precursors.

- The exact method for producing CaO-NP from the plant extract is not clearly defined.
- Careful examination of the plants or plant materials used is necessary to get a complete understanding of how the item works.
- The capacity to produce calcium oxide nanoparticles (CaO-NPs) independently is known to exist in some plants. An array of medicinal plants is thus necessary for the synthesis of CaO-NPs.
- Hydrogen generation, biosensor creation, medication delivery, and agricultural support are just a few of the many applications for environmentally friendly CaO-NPs.

5. CONCLUSION

The current surge in research into producing CaO nanoparticles from various plant materials is examined in this study to provide light on the topic and ensure its broad applicability. The catalyst can be used as a bio-ceramics adsorbent to break down tissue, promote drug distribution, and reduce air pollution emissions. The development of novel, cost-effective, and environmentally benign processes involving live organisms has led to the synthesis of nanoparticles. These are better than the complicated, risky, and outmoded chemical and physical approaches. Plants continue to play an important role in maintaining ecosystem stability, therefore finding CaO nanoparticles and selecting appropriate plant species to achieve our goal while preserving their diversity will require innovative strategies.

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