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Green Extract Mediated Synthesis of Cerium Nitrate Hexahydrate by Using Banana Rim for the Evaluation of Antibacterial Efficacy

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ABSTRACT

This work deals with the systematic study of structural, optical and antibacterial study of $CeNO_3$ and green extract of banana rim. Natural plant extracts and cerium nitrate $CeNO_3$ have attracted attention because of their possible synergistic effects in biological applications. This study examines the antibacterial, wound-healing, and antioxidant qualities of a green plant extract in conjunction with $CeNO_3$. These substances stabilize cerium ions when coupled with $CeNO_3$, which may lessen cytotoxicity while increasing the bioavailability and effectiveness of cerium ions. These results demonstrate the potential of $CeNO_3$ in conjunction with green extracts to create cutting-edge wound care products and antioxidant treatments. To clarify the underlying mechanisms and improve the formulation for therapeutic applications, more research is necessary. Furthermore, the combination shows enhanced antimicrobial activity in tests against common pathogenic bacteria (E. coli and S. aureus), which may make it appropriate for use as a wound dressing.

Keywords: Banana rim green extract, CeO2 nanoparticles, Wound healing.

1 Introduction

Cerium nitrate hexahydrate has distinctive biological qualities and uses, particularly because cerium ions can change between two oxidation states (Ce^{3+} and Ce^{4+}), which affects oxidative processes and scavenges radicals. Because of its high antioxidant properties free radicals can be scavenged by cerium ions, especially Ce^{4+}, which can function as antioxidants. This helps biological systems reduce oxidative stress, which is connected to aging and cellular damage [1]. Owing to its oxidative characteristics, cerium nitrate hexahydrate is being studied for use in wound healing and regenerative medicine. Treatments for conditions where cell protection is essential may be developed with the use of the compound's capacity to influence oxidative stress [2]. In antimicrobial therapies, cerium compounds, such as cerium nitrate, exhibit promise. By interfering with bacterial cell walls, cerium ions can help keep burns and wounds from becoming infected. Ce NPs are being investigated as possible constituents of synthetic enzymes, as well as in connection with a number of inflammatory and cardiovascular disorders. Results in laboratory settings have been encouraging, and research on their biocompatibility is ongoing [3].

Combining natural extracts with cerium compounds (especially cerium oxide nanoparticles) is an emerging area in biomedical research. This approach leverages the biological activity of natural compounds alongside cerium's antioxidant, antibacterial, and wound-healing properties. The antioxidant content of many natural extracts, including those from green tea, curcumin (from turmeric), and resveratrol (from grapes), can be increased when combined with cerium oxide nanoparticles (Ce NPs). This synergy is especially promising in preventing damage caused by oxidative stress, such as in neurodegenerative diseases or skin aging. Ce NPs function as "artificial enzymes," and natural antioxidants enhance their capacity to scavenge radicals, which may result in more robust and long-lasting antioxidant defence. Cerium nanoparticles may be more

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compatible with human tissues if they are coated or stabilized by natural extracts. For example, polyphenols, which are antioxidants present in a variety of plants, can cover Ce NPs with a biocompatible layer that may lessen any negative effects on human cells. By improving control over the release and reactivity of the nanoparticles, the use of natural chemicals as stabilizers for cerium nanoparticles can assist address certain safety concerns, such as the danger of oxidative damage in healthy cells [4].

Calendula, chamomile, and aloe vera are a few plant extracts that are well-known for their calming and restorative properties. They could provide a potent combination for wound healing when paired with cerium oxide nanoparticles. These extracts' inherent anti-inflammatory properties enhance cerium's capacity to lower oxidative stress and promote cell repair, which may hasten healing and lessen scarring. This combination could be used to prevent infection and promote tissue regeneration in burn, chronic wound, or surgical incision dressings or sprays. Cerium oxide nanoparticles in combination with natural antimicrobials like cinnamon, tea tree oil, and garlic extract may offer strong antibacterial defence. While cerium oxide increases antimicrobial action by making the environment unsuitable for bacterial growth, the natural extracts are effective against a variety of microorganisms. Since resistant bacteria can cause serious problems in medical implants, catheters, and wound dressings, this synergy may be perfect for preventing infections in these areas [5].

Certain natural extracts, such as quercetin and curcumin, have demonstrated potential in cancer research because they can cause cancer cells to undergo apoptosis, or programmed cell death. When combined with cerium oxide nanoparticles, these extracts may have a double effect: the natural extracts may aid to stop the proliferation of cancer cells, while the cerium nanoparticles may specifically target oxidative stress in cancer cells. These combinations have the potential to lessen side effects by enabling tailored therapy that spares healthy cells, although they are still primarily experimental. For natural extracts, cerium oxide nanoparticles can serve as transporters, improving the stability and delivery of sensitive substances that might otherwise break down or lose their effectiveness. To enhance their absorption in the body and maybe increase the efficacy of treatments, flavonoids and polyphenols derived from plants, for instance, might be loaded onto cerium oxide nanoparticles [6]. In this study, we introduce a novel synthetic method for producing CeO_2 NPs using banana rim as a green extract. This method is economical and environmentally friendly, and the abundant phytochemicals in the banana rim play a variety of roles in the reduction, stabilization, and fine distribution of nanoceria through oxidation–reduction (redox) reactions. Additionally examined and clarified are the pertinent physicochemical characteristics that impact the biological production of CeO_2 NPs mediated by green extract.

2 Materials and Methods

To get the green extract 10g Banana Leaf Rim and 100 ml D.W was mixed thoroughly with stirrer and green extract were collected separately. Then 50 ml of green extract was added with 50 ml of 0.2 M (Cerium nitrate hexahydrate) and hence we collect the sample of (50% $CeNO_3$+50% Green extract). Likewise, 60 ml of green extract + 40 ml of 0.2 M $CeNO_3$ (40% $CeNO_3$+60% Green extract) and 70 ml of green extract + 30 ml of 0.2 M $CeNO_3$ (30% $CeNO_3$+70% Green extract) samples were collected. Then all samples are muffle furnaced for 2Hrs under 200˚C. After that all the samples were used for the characterisation process.

3 Result and Discussion

3.1 XRD Analysis

Figures 1a,1b,1c illustrates the XRD pattern of bio fabricated $CeNO_3$ and green extract of various percentage combinations. The presence of six diffraction peaks corresponds to (111), (200), (220), (311), (222) and (400) crystallographic planes are precisely well matched to (JCPDS) (card no 96-900-9009). A single-phase cubic fluorite structure with eight oxygen sites occupying each cerium site in a face-centered cubic way (a = b = c = 5.14, α = β = γ = 90°) is demonstrated by the observed crystal lattice for biogenic $CeNO_3$ NPs [7]. From the XRD studies it is clear that by reducing the proportion of the green extract the $CeNO_3$ peaks get the clear presence on the pattern. The sharp peaks at the range of 28.54˚clearly reveals the peak structure of $CeNO_3$ NPs.

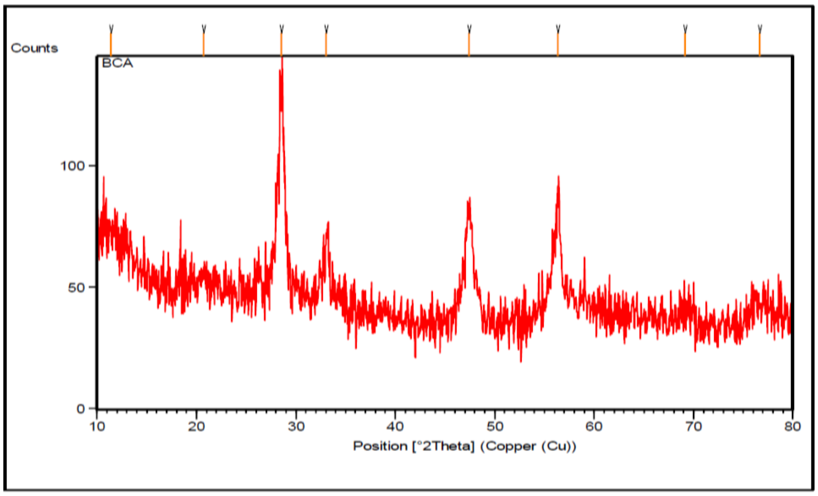

Fig-1a: XRD pattern of $CeNO_3$-50% and Green Extract-50%

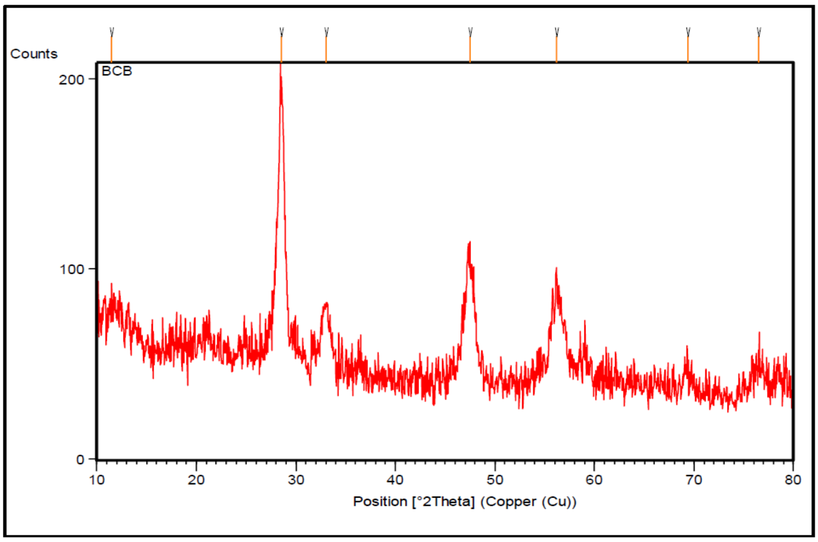

Fig-1b: XRD pattern of $CeNO_3$-60% and Green Extract-40%

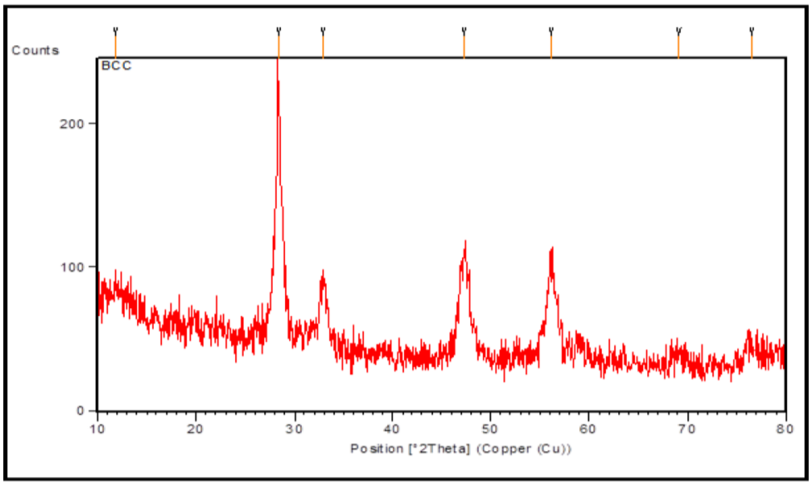

Fig-1c: XRD pattern of $CeNO_3$-70% and Green Extract-30%

3.2 UV Analysis

The primary visual observation of the samples confirmed the $CeNO_3$ NPs by changing the colour of the solution from light green to pale yellow slurry formation. The sharp absorption peaks at 252nm (fig.2) confirms the optical absorption behaviour of the $CeNO_3$ and Green extract by Diffuse Reflectance UV-Vis Spectroscopy [8]. Normally the peaks of 310nm will be measured as a $CeNO_3$ spectrum but the presence of banana rim green extract the spectrum are supposed to found out at the wavelength of 252nm.

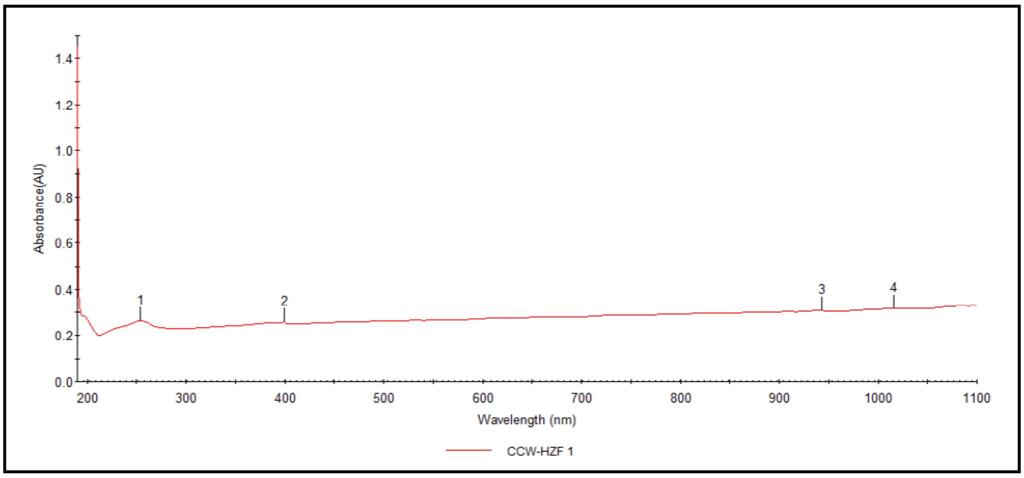

Fig-2: UV-Vis Spectra of $CeNO_3$ and Green Extract NPs

3.3 FTIR Analysis

FTIR analysis of the sample's surface chemistry was performed, and Fig.3 shows the associated spectrum of green extract CeO_2 NPs, which shows the existence of several bands. The broad and strong absorption peak at 3450 cm^{-1} is attributed to the numerous hydroxyl groups, O–H, and N–H stretching caused by water, carbohydrates, polyphenols, and most likely proteins; the band at 2915 cm^{-1} is linked to the aliphatic symmetric C–H group stretching of carbohydrates; the characteristic vibration band of the carbonyl group (C=O) was observed at 1755 cm^{-1}; the weak C–H bending band of alkane compounds appeared at 1365 cm^{-1}; the ether functional group (C–O–C) linkage related to polysaccharides is centered at 1058 cm^{-1}; and the quite strong stretching peak around 1000 cm^{-1} is associated with C–OH of primary and secondary alcohols [9].

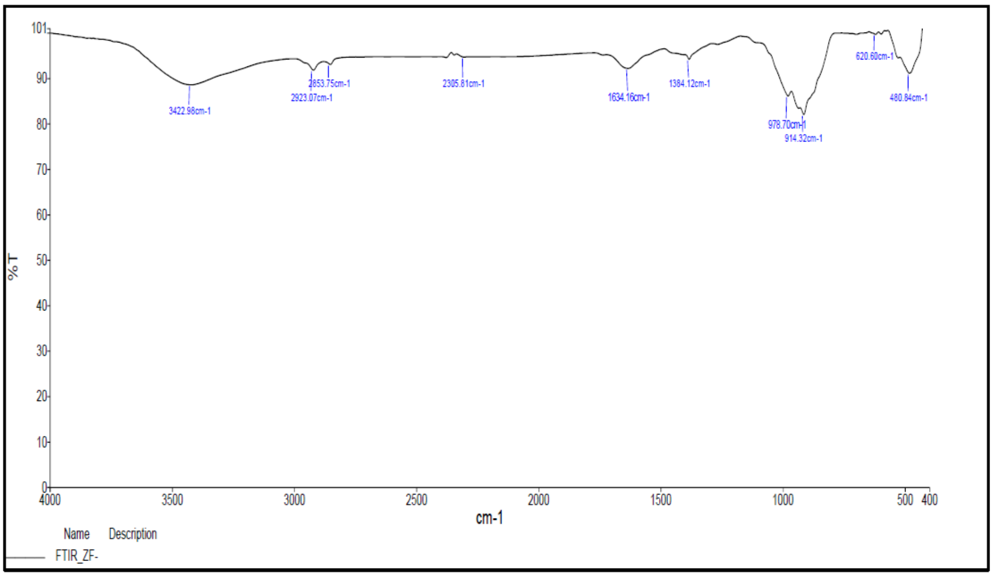

Fig-3: FTIR Pattern for $CeNO_3$ and Green Extract NPs

Regarding the reduction process, cerium cations served as an electron acceptor (the oxidizing agent) and electron-rich biomolecules (the reducing agent) as an electron donor through a redox reaction. Lastly, similar studies have shown that the generated metallic cerium atoms may easily form CeO_2 nanoparticles when exposed to oxygen in the air, demonstrating the bio fabrication of nanoparticles via a variety of biological derivatives [10].

3.4 SEM Analysis

Figures 4a,4b,4c show the SEM image of a $CeNO_3$ and Green Extract (banana rim). From the image it's clear that the agglomeration formation of the samples is imaged and based on the concentration the agglomeration got varied. The images also reveal that NPs are like tiny spherical particle and it forms an agglomerated condition. It's also known that if the green extract concentration gets decreased then the particle size gets increased and this is shown in the table 1.

Table1: *Increase in the Particle size with reduction in the extract concentration*

S. No	Samples	Reduction in Particle Size
1.	50%(CeNO3) + 50% (Banana rim green extract)	90.69nm
2.	60%(CeNO3) + 40% (Banana rim green extract)	109.9nm
3.	70%(CeNO3) + 30% (Banana rim green extract)	146.7nm

From the SEM analysis it's clear that the adding of green extract will make drastic change in the morphology of the $CeNO_3$ NPs and from that it's know that the microbial studies will also play a major role for the samples having different morphological approaches. Reduction in particle size leads to penetrate easily through the walls of the microbes and because of that microbials destruction starts to carried out.

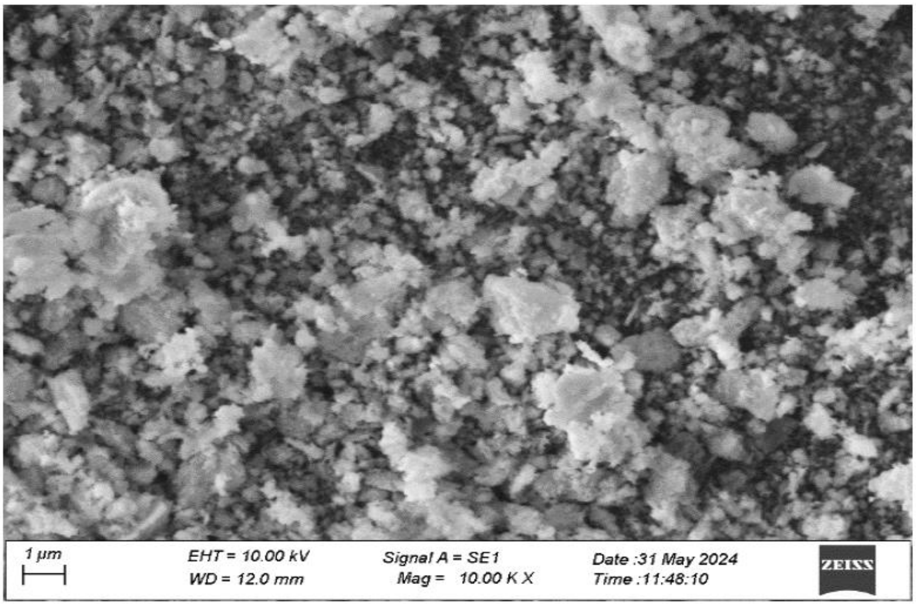

Fig-4a: SEM image of $CeNO_3$-50% and Green Extract-50%

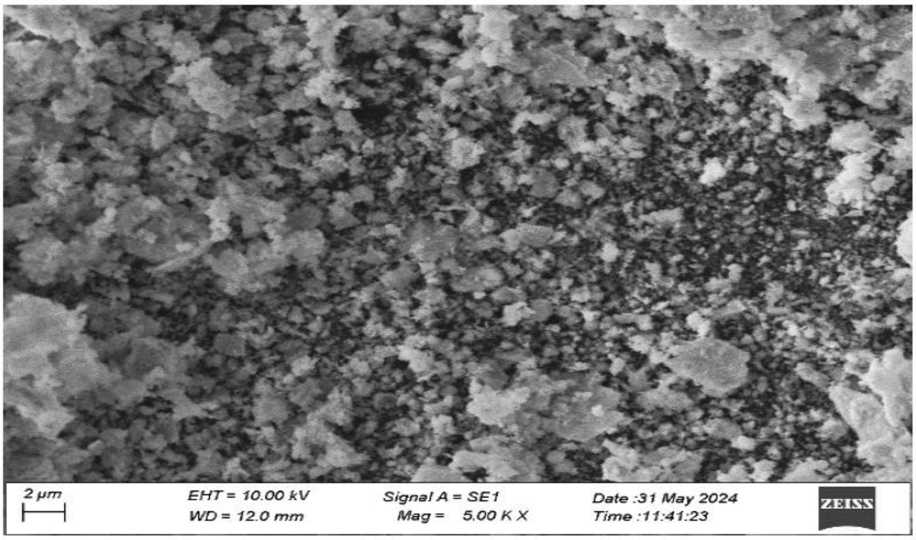

Fig-4b: SEM image of $CeNO_3$-60% and Green Extract-40%

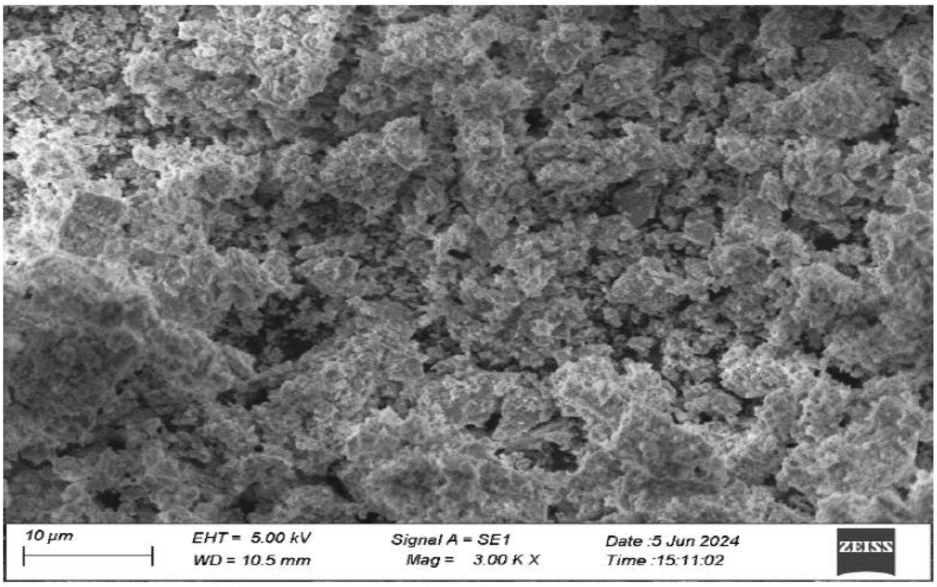

Fig-4c: SEM image of $CeNO_3$-70% and Green Extract-30%

4 Conclusion

In conclusion, we have used banana rim green plant extract to create $CeNO_3$ NPs utilizing a unique synthetic process. Based on FTIR and UV investigations, the biomolecules isolated from banana rim serve as stabilizing agents and bio reductants in the environmentally friendly nanoceria manufacturing process. The metallic cations in a cerium solution were reduced into matching nanoceria under benign and nontoxic reaction conditions when electron-donor green extract biomolecules were present. The agglomerated spherical structure of biogenic $CeNO_3$ NPs without any impurities was confirmed by XRD and SEM data. The particle sizes range from 90.69 nm to 146.7 nm, which are dispersed according to the change in the concentration of $CeNO_3$ and green extract.

6 Declarations

6.1 Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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