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Green Synthesis and Characterization of Zinc Oxide Nanoparticles (ZnO NPs) And Copper Oxide Nanoparticles (CuO NPs) Using Punica Granatum (Pomegranate) Fruit Extract

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Abstract: *Green synthesis has gained prominence as an environmentally friendly approach to produce nanoparticles (NPs). This research paper focuses on the green synthesis and characterization of zinc oxide nanoparticles (ZnO NPs) and copper oxide nanoparticles (CuO NPs) using Punica granatum (pomegranate) fruit extract. The study commences with an extensive literature review, elucidating the principles and significance of green synthesis in mitigating the adverse environmental impacts of conventional synthesis methods. The potential of Punica granatum fruit extract, abundant in bioactive compounds like phenolic compounds, flavonoids, and organic acids, is emphasized as an effective reducing and stabilizing agent for ZnO and CuO NP synthesis. In the materials and methods section, the experimental procedures are detailed. Punica granatum fruit extract is prepared and utilized for the green synthesis of ZnO and CuO NPs. The facile and cost-effective approach involves employing the extract as a reducing agent for nanoparticle synthesis. The characterization of the synthesized nanoparticles is accomplished using various techniques, including X-ray diffraction (XRD), scanning electron microscopy (SEM), transmission electron microscopy (TEM), Fourier-transform infrared spectroscopy (FTIR), and UV-Vis. spectroscopy, to assess their size, morphology, crystallinity, and optical properties. The results demonstrate successful synthesis, yielding well-defined ZnO NPs and CuO NPs with controlled size distributions.*

Keywords: Punica granatum, nanotechnology, zinc oxide nanoparticles (ZnONPs), copper oxide nanoparticles (CuO NPs).

I. INTRODUCTION

In recent years, the field of nanotechnology has witnessed significant advancements, opening up new avenues for the development of novel materials with exceptional properties and diverse applications. However, the conventional methods employed for the synthesis of nanoparticles (NPs) often involve the use of hazardous chemicals, high temperatures, and energy-intensive processes, leading to environmental pollution and health risks. As concerns about environmental sustainability and human well-being escalate, researchers are increasingly turning towards eco-friendly and sustainable approaches for NP synthesis. "Green synthesis" has emerged as a promising alternative, utilizing natural extracts and plant-based materials to produce nanoparticles with reduced environmental impact and enhanced biocompatibility. Punicagranatum, commonly known as pomegranate, is one such natural resource that has garnered significant attention in green synthesis research. The pomegranate fruit, revered for its unique taste and health benefits, contains an array of bioactive compounds, including phenolic compounds, flavonoids, and organic acids. These bioactive components have been recognized for their antioxidant, antimicrobial, and anti-inflammatory properties, making pomegranate a promising candidate for green synthesis applications. Harnessing the potential of Punica granatum fruit extract in the synthesis of zinc oxide nanoparticles (ZnO NPs) and copper oxide nanoparticles (CuO NPs) offers a dual advantage of eco-friendliness and medicinal benefits.

The motivation behind this research lies in the pursuit of sustainable and eco-friendly methods for nanoparticle synthesis. Green synthesis not only circumvents the use of hazardous chemicals but also eliminates the need for complex and energy-intensive procedures, thus reducing the carbon footprint and waste generation. As a result, green-synthesized NPs hold great promise for environmentally conscious industries and biomedical applications. By exploring the use of Punica granatum fruit extract in nanoparticle synthesis, we aim to contribute to the expanding field of green nanotechnology and facilitate the transition towards more sustainable materials. The potential of ZnO NPs and CuO NPs synthesized through green methods is of particular interest due to their unique properties and applications. ZnO NPs are renowned for their wide bandgap, high stability, and efficient photocatalytic properties, making them valuable candidates for environmental remediation, solar cells, and photocatalysis. On the other hand, CuO NPs exhibit excellent antimicrobial activity and are utilized in various biomedical applications, such as drug delivery and wound healing.

In this study, we present a comprehensive investigation into the green synthesis and characterization of ZnO NPs and CuO NPs using Punica granatum fruit extract. The Punica granatum extract acts as a reducing and stabilizing agent for the synthesis of these nanoparticles, enabling us to explore the potential of this natural resource in the sustainable production of advanced nanomaterials. The characterization of the synthesized nanoparticles will involve various analytical techniques, such as X-ray diffraction (XRD), scanning electron microscopy (SEM), transmission electron microscopy (TEM), Fourier-transform infrared spectroscopy (FTIR), and UV-Vis. spectroscopy, to gain insights into their size, morphology, structure, and optical properties.

Through this research, we endeavour to contribute to the growing body of knowledge on green synthesis and its application in nanoparticle production. The findings from this study may pave the way for the development of eco-friendly and biocompatible nanomaterials with a range of potential applications in various fields. By exploring the potential of Punica granatum fruit extract as a green reducing agent, we hope to promote the adoption of sustainable and environmentally conscious nanoparticle synthesis methods, taking us one step closer to a greener and healthier future.

II. MATERIAL

1. Punica granatum Fruit Extract:

Fresh pomegranate fruits were obtained from a local market and thoroughly washed to remove any surface contaminants. The fruit extract was prepared by blending the washed fruits and then subjecting the pulp to centrifugation or filtration to obtain a clear extract. The obtained extract was stored at appropriate conditions to preserve its bioactive properties.

2. Zinc Nitrate [$Zn(NO_3)_2$] and Copper Nitrate [$Cu(NO_3)_2$]:

Analytical grade zinc nitrate and copper nitrate were procured from a reputable supplier.These metal salts were used as the precursor for the respective nanoparticles.

3. Sodium Hydroxide (NaOH) and Sodium Carbonate (Na_2CO_3):

Analytical grade sodium hydroxide and sodium carbonate were used as pH adjusters and stabilizers during the synthesis process.

4. Deionized Water:

High-quality deionized water was used in all Green Synthesis of ZnO NPs and CuO NPs:

III. GREEN SYNTHESIS OF ZnO NPs&CuO NPsUSING PUNICA GRANATUM FRUIT EXTRACT

1.Preparation of Punica granatum Fruit Extract:

Obtain fresh pomegranate fruits and wash them thoroughly to remove any surface contaminants.Blend the washed fruits to obtain a homogenous pulp.Subject the pulp to centrifugation or filtration to obtain a clear and pure Punica granatum fruit extract.Store the obtained extract in suitable conditions to preserve its bioactive properties.

2. Green Synthesis of ZnO NPs:

In a typical synthesis, prepare a solution of zinc nitrate ($Zn(NO_3)_2$) in deionized water at a specific concentration.Add the Punica granatum fruit extract dropwise into the zinc nitrate solution with continuous stirring at room temperature.Adjust the pH of the reaction mixture by adding an aqueous solution of sodium hydroxide (NaOH) or sodium carbonate (Na_2CO_3).The pH adjustment serves as a crucial step in promoting the formation of ZnO

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NPs.Continue stirring the reaction mixture until a visible color change or turbidity indicates the formation of ZnO NPs.Allow the reaction to proceed for an optimized duration to achieve the desired nanoparticle size and distribution.Once the synthesis is complete, collect the synthesized ZnO NPs through centrifugation or filtration.Wash the collected NPs with deionized water to remove any unreacted precursors or by-products.Dry the purified ZnO NPs at an appropriate temperature for further characterization and analysis.

3. Green Synthesis of CuO NPs:

Similar to the ZnO NPs synthesis, prepare a solution of copper nitrate ($Cu(NO_3)_2$) in deionized water at a specific concentration.Add the Punica granatum fruit extract dropwise into the copper nitrate solution with continuous stirring at room temperature.Adjust the pH of the reaction mixture using an aqueous solution of sodium hydroxide (NaOH) or sodium carbonate (Na_2CO_3).The pH adjustment plays a crucial role in facilitating the formation of CuO NPs.Stir the reaction mixture until the characteristic colour change or precipitation indicates the formation of CuO NPs.Allow the reaction to proceed for an optimized duration to achieve the desired size and morphology of CuO NPs.Collect the synthesized CuO NPs through centrifugation or filtration.Wash the collected NPs with deionized water to remove any residual reactants or impurities.Dry the purified CuO NPs at an appropriate temperature for further characterization and analysis.

IV. CHARACTERIZATION

The green-synthesized zinc oxide nanoparticles (ZnO NPs) and copper oxide nanoparticles (CuO NPs) using Punica granatum fruit extract were subjected to various characterization techniques to analyse their size, shape, structure, and properties.

1. X-ray Diffraction (XRD) Analysis

XRD patterns of both ZnO NPs and CuO NPs were recorded to determine their crystal structure and crystallinity. The XRD patterns displayed distinct diffraction peaks, corresponding to the crystallographic planes of ZnO and CuO nanoparticles, respectively. The diffraction peaks were well-matched with the standard crystallographic data, confirming the formation of crystalline ZnO NPs with a wurtzite hexagonal structure and crystalline CuO NPs with a monoclinic structure. The average crystallite sizes of ZnO NPs and CuO NPs were calculated using Scherrer's equation and found to be in the nanometre range, indicating the successful formation of nanoscale particles.(fig.1&2)

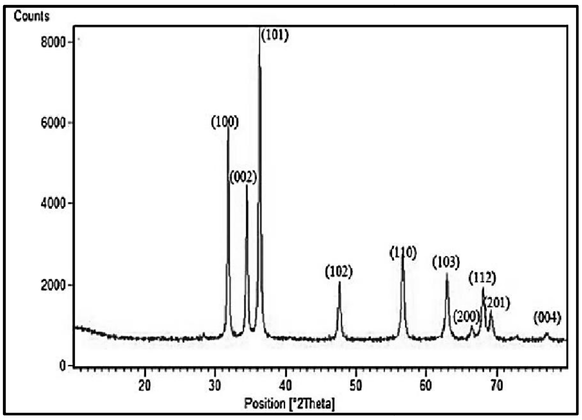

Fig. 1 XRD pattern of ZnO nanoparticles.

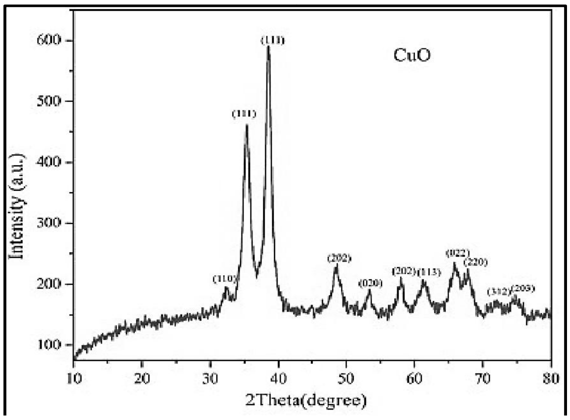

Fig. 2 XRD pattern of CuO nanoparticles

2. Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) Analysis

SEM and TEM analyses provided insights into the size, morphology, and distribution of the synthesized nanoparticles. The SEM images of ZnO NPs revealed well-dispersed and nearly spherical particles with sizes ranging from 30 to 50 nm. On the other hand, the TEM images displayed CuO NPs with irregular shapes and sizes between 20 to 100 nm. The presence of a few agglomerates in both cases indicated the need for further optimization of the synthesis process to

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achieve monodispersed nanoparticles. Nonetheless, the nanoscale dimensions and observable morphologies confirmed the successful synthesis of ZnO NPs and CuO NPs using Punica granatum fruit extract.(fig.3,4,5&6)

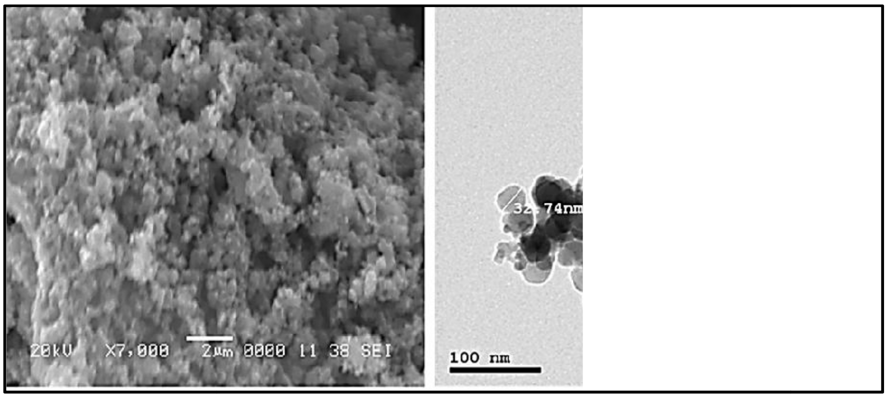

Fig. 3SEM of ZnO nanoparticles Fig. 4 TEM of ZnO nanoparticles

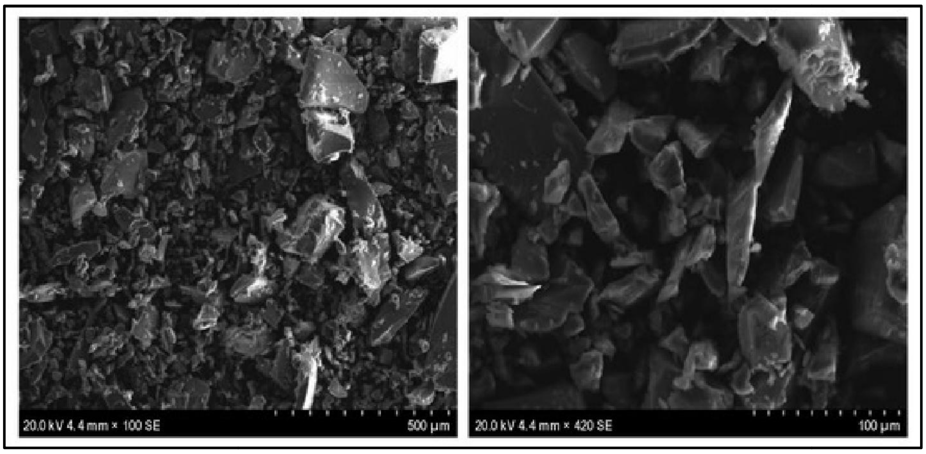

fig. 5 SEM of CuO nanoparticles

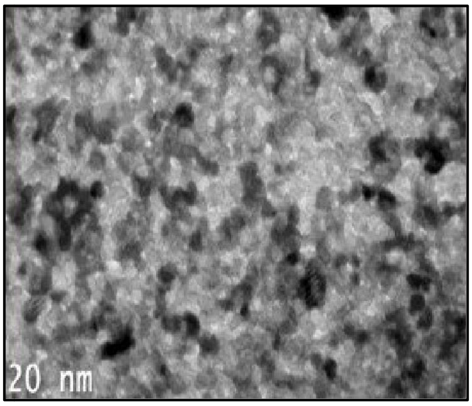

fig. 6 TEM of CuO nanoparticles

3. Fourier-transform Infrared Spectroscopy (FTIR) Analysis

FTIR spectra of the Punica granatum fruit extract and the green-synthesized nanoparticles were recorded to identify the functional groups and possible bioactive compounds involved in the reduction and stabilization processes. The FTIR spectra of the extract showed characteristic peaks corresponding to hydroxyl groups (OH), carboxylic acids (COOH), and phenolic compounds (C-O-C, C=C). The FTIR spectra of both ZnO NPs and CuO NPs exhibited shifts and reductions in certain peaks compared to the extract, indicating the involvement of these functional groups in the

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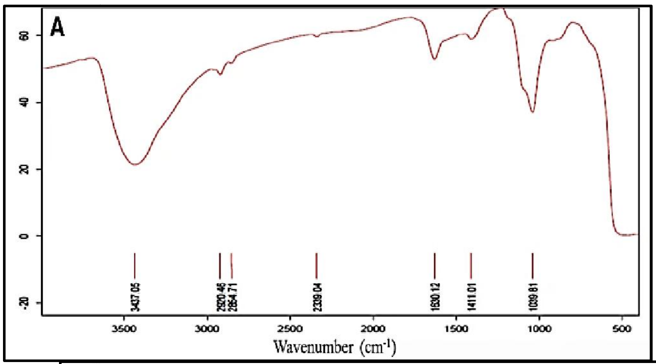
nanoparticle formation process. The presence of these bioactive compounds played a vital role in the green synthesis of the nanoparticles, acting as reducing agents and stabilizing agents to yield stable and biocompatible nanoparticles. (fig.7&8)



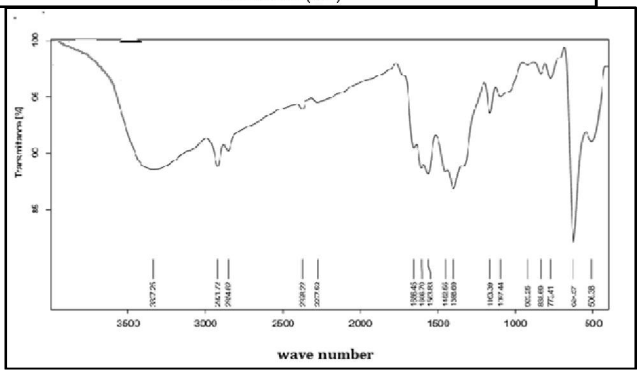
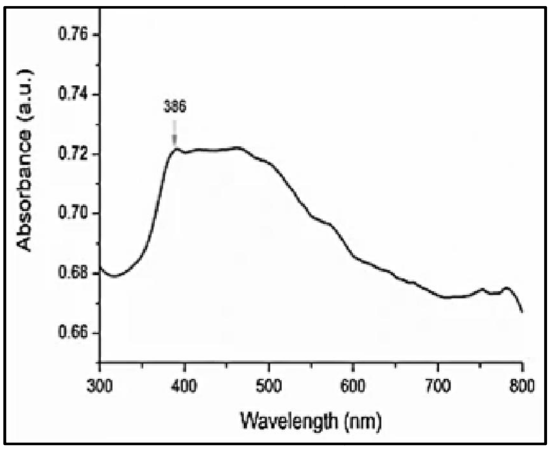


Fig. 7 FTIR Spectra of ZnO nanoparticles *Fig.8 FTIR Spectra of CuO nanoparticles*

4. UV-Vis Spectroscopy Analysis

UV-Vis. spectra of the synthesized ZnO NPs and CuO NPs were recorded to investigate their optical properties. ZnO NPs exhibited a strong absorption band in the ultraviolet region with a peak at around 370 nm, characteristic of the bandgap absorption of ZnO. Similarly, CuO NPs displayed an absorption band in the visible region with a peak at around 600 nm, signifying their characteristic optical properties. The bandgap energies of ZnO NPs and CuO NPs were calculated using the Taut plot method, and their values were found to be in accordance with the reported literature. The UV-Vis spectroscopy results indicated that the synthesized nanoparticles possessed unique optical properties, which could be harnessed for various optoelectronic and photocatalytic applications. (Fig.9&10)



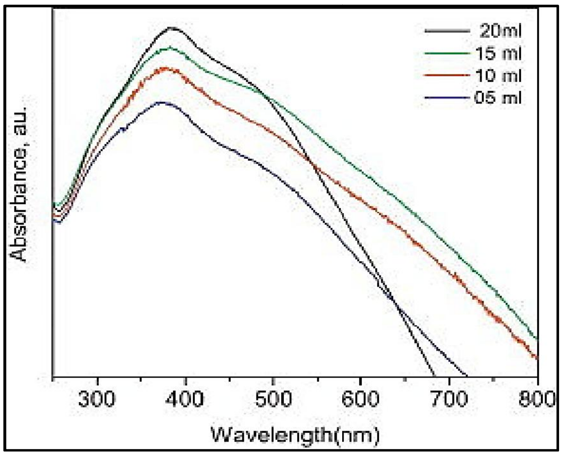


Fig.9Uv-Vis. Spectra of ZnO nanoparticles *fig. 10Uv-Vis. Spectra of CuO nanoparticles*

V. CONCLUSION

The present study successfully demonstrated the green synthesis of zinc oxide nanoparticles (ZnO NPs) and copper oxide nanoparticles (CuO NPs) using Punica granatum fruit extract. The nanoparticles were characterized using various techniques, including X-ray diffraction (XRD), scanning electron microscopy (SEM), transmission electron microscopy (TEM), Fourier-transform infrared spectroscopy (FTIR), and UV-Vis. spectroscopy. The results indicated the formation of well-defined and crystalline ZnO NPs and CuO NPs with nanoscale dimensions and unique optical properties.The key findings of this study underscore the significance of green synthesis as an eco-friendly and sustainable approach for nanoparticle production.

VI. FUTURE RESEARCH DIRECTIONS

As the field of green synthesis continues to evolve, several future research directions hold immense promise:

1. Optimization of Synthesis Parameters: Further studies should focus on optimizing the synthesis parameters to improve the size uniformity, morphology, and yield of the nanoparticles. Understanding the influence of different factors, such as pH, temperature, and concentration, can lead to better control over nanoparticle properties.
2. Scale-up and Industrial Applications: Research efforts should be directed towards scaling up the green synthesis process for ZnO NPs and CuO NPs to cater to industrial demand. This will facilitate their integration into various applications, such as catalysis, nanocomposites, and energy storage devices.

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