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Biomimetic Synthesis of CuO Nanoparticle using *Capparis decidua* and their Antibacterial Activity

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ABSTRACT. In this study, a simple approach for the biomimetic synthesis of copper oxide nanoparticle (CuO NP) using *Capparis decidua* bark extract (CDBE) was investigated. The biogenic synthesis of CuO NP was explored by XRD, SEM, EDX and TEM studies. XRD data shows the formation of monoclinic crystalline structures of CDBE mediated CuO NP. SEM images show that the NPs have quasi-spherical shape and the mean diameter were found to be 5-40 nm. These perceptions were affirmed by HRTEM analysis. CDBE mediated CuO NP shows significant bactericidal performance against three pathogenic bacteria such as *Bacillus subtilis*, *Staphylococcus aureus* and *Escherichia coli*. The study reveals a straightforward, eco-benign and vigorous approach for the biomimetic production of CuO NP using therapeutic plants.

Keywords: Nanotechnology; CuO; Nanoparticle; *Capparis decidua*; Antibacterial activity; Green synthesis.

INTRODUCTION

Nowadays, production of nanoparticle (NP) using conventional approaches is very costly and requires rigorous steps. Hence, developing straightforward, clean, one pot, biocompatible, rapid, non-noxious and eco-accommodating protocols are gaining peculiar importance in modern nanoscience using enzymes, microorganisms, biopolymers and plant extracts.[1-15] Among the divergent biomimetic synthetic methodologies, the use of therapeutic plant extracts has received crucial consideration as they are easily available, safe to handling and have wide variability of active biomolecules. The phytoconstituents and/or active biomolecules such as flavonoids, saponins, tannins, carbohydrates, steroids, phenols, proteins and amino acids, coumarins, alkaloids and terpenoids present in the plant extracts play a crucial and efficient role in the production of NP.[16-25] Biomimetic fabrication of CuO NP using plant extracts of *Acanthospermum hispidum*,[26] *Lantana camara*,[27] *Moringa oleifera*,[28] *Plectranthus amboinicus*,[29] *Leucaena leucocephala*,[30] *Citrofortunella microcarpa*,[31] *Euphorbia maculata*,[32] *Ziziphus mauritiana*,[33-34] and *Euphorbia pulcherrima*[35] have been investigated.

Metal oxide nanomaterials can be fabricated with improbably high surface areas, and are more appropriate for eclectic and multifunctional biological applications.[26, 36] CuO is a *p*-type semiconductor with interesting features/properties such as low toxicity, good thermal and chemical stability, low cost, high catalytic reusability and easy to handling (Fig. 1).[1, 28, 37] Moreover, CuO NP is extensively used for the broad range of multifunctional applications. For instance, high-temperature superconductors,[38, 39] solar cells,[40] gas sensors,[41] lubricant,[42] optical applications,[43] catalytic applications,[44] and medical applications.[26, 37]

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Capparis decidua is belonging to family *Capparidaceae*, yet significant therapeutic plant. In the traditional system of medicine, the bark has been investigated for the treatment of asthma, coughs and inflammation.[45] The *Capparis decidua* is accounted for to contain secondary phytochemicals and/or active biomolecules including terpenoids, alkaloids, glycosides and few fatty acids. Moreover, *Capparis decidua* has remarkable pharmacological efficacies like anti-inflammatory, hypercholesterolemia, analgesic, antimicrobial, antidiabetic, antihypertensive and purgative activities.[45]

In this work, we investigated the biomimetic fabrication of CuO NP using a bark extract of *Capparis decidua* and we evaluated its antibacterial efficacies by utilizing against three bacterial strains. It was found that biogenically fabricated CuO NP manifested curative biomedical application in the area of nanomedicine.

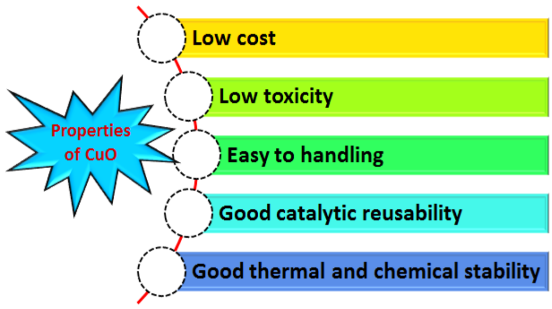

Fig. 1: Properties of CuO NP.

MATERIALS AND METHODS

Materials

Copper acetate monohydrate (Sigma-Aldrich) was used without purification and required solutions were prepared using deionized water during the fabrication of CuO NP. The bark of *Capparis decidua* was sourced from Sinnar, Maharashtra, India.

Green Synthesis of CuO NP

A sample of 2 g powder of *Capparis decidua* bark was transferred into beaker containing 100 mL double distilled water. It was heated at 100 °C for 10 min and allowed to cool down at room temperature. Afterwards, resultant mixture was filtered through quantitative filter paper. The filtered *Capparis decidua* bark extract (CDBE) was kept at 4 °C for further biomimetic synthesis of CuO NP. The CDBE was added to 0.01 M copper acetate monohydrate solution in 1:1 ratio. Before that, different ratios like 1:2, 1:3, 1:4 and 1:5 were also checked as a part of reaction optimization but best results were obtained for 1:1 ratio. The color change from pale yellow to dark green was observed after addition of copper acetate to CDBE which time being changed to black color after stirred magnetically. The black solid product obtained was centrifuged at 4000 rpm for 15 min. After removal of unwanted supernatant liquid, the obtained product was kept in pre-heated muffle furnace at 400 °C temperature (1 h) for combustion. These fine black colored products was collected, ground and stored in vial (Fig. 2).

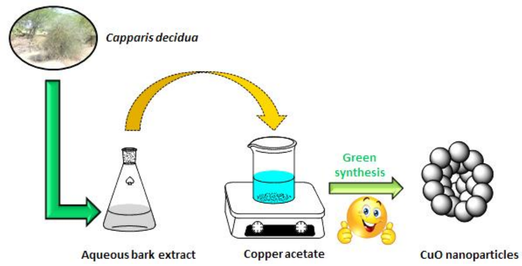

Fig. 2: Scheme of biomimetic synthesis of CuO NP.

Characterization Techniques

The crystal structure analysis of the CuO NP was analyzed by X-ray diffraction (XRD, Brukar, D8-Advanced Diffractometer). Morphological analysis and elements mapping of the CuO NP were examined by scanning electron microscopy (SEM-VEGA3 TESCAN), and energy dispersive X-ray analysis (EDX) for elemental mapping were conducted using the same instrument. High-resolution transmission electron microscopy (HRTEM, FEI-Tecnai TF 20) were also analyzed.

Antibacterial Activity

The bactericidal performance of CDBE mediated CuO NP were conducted against three bacterial strains includes *Bacillus subtilis* MTCC 441, *Escherichia coli* MTCC 44, and *Staphylococcus aureus* MTCC 96 compared with ampicilline as a standard drug. This antibacterial efficacy was conducted in accordance with experiment in Rattan et al.[24] and Bangale et al.[46] The highest dilution reading display at least 99% inhibition has taken as a minimum inhibition concentration (MIC) value.

RESULTS AND DISCUSSION

Structural and Crystallographic Analyses

Fig. 3 shows the XRD profile at 32.56º, 35.52º, 38.76º, 48.78º, 53.54º, 58.32º, 61.58º, 66.28º, 68.1º, 72.5º, and 75.22º, corresponding to (110), (-111), (111), (-202), (020), (202), (-113), (022), (-221), (311) and (004) crystal planes, respectively. The XRD profile revealed that CuO NP has monoclinic structure, which was affirmed by the JCPDS card no. 01-080-1268. The mean diameter size of the CuO NP was calculated using Debye-Scherrer's equation[47] which was around 5±1 nm.

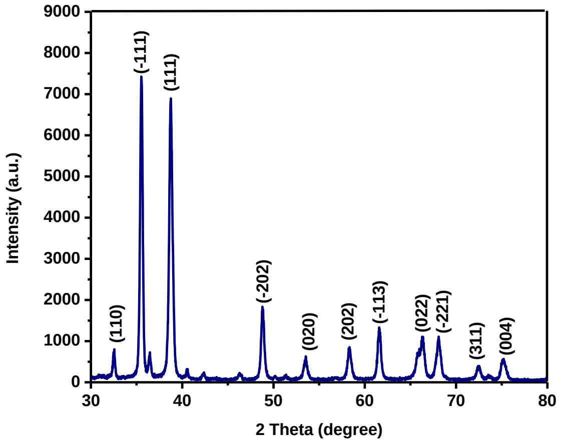

Fig. 3: X-Ray diffraction profile of CDBE mediated CuO NP.

SEM Image

Morphological features of biogenically synthesized CuO NP were conducted by SEM analysis. It could be seen that the median particle size of the CuO NP was mainly 5-40 nm having quasi-spherical and uneven shapes due to slight agglomeration (Fig. 4).

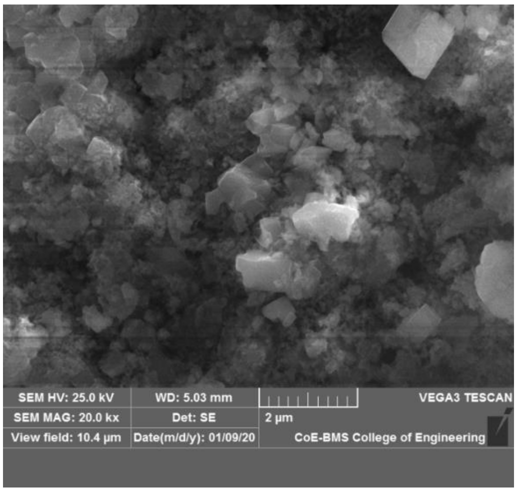

Fig. 4: SEM image of CDBE mediated CuO NP.

EDX Studies

The elemental composition of biogenically fabricated CuO NP has been examined by EDX, as depicted in Fig. 5. This was carried out to understand the elemental mapping of the copper and oxygen. The EDX spectrum consists of prominent peaks of Cu and O. The prominent peaks of Cu and O in EDX spectrum clearly shows the CuO NP formation using CDBE as a fuel.

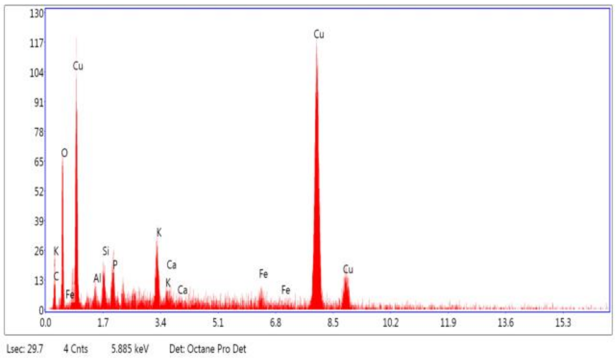

Fig. 5: EDX spectrum of biosynthesized CuO NP.

HRTEM Images

HRTEM was analyzed to know the morphology, median particle size and crystallinity of the CDBE mediated CuO NP. The HRTEM images of the synthesized CuO NP are depicted in Fig. 6. It shows quasi-spherical and uneven shapes for the fabricated CuO NP.

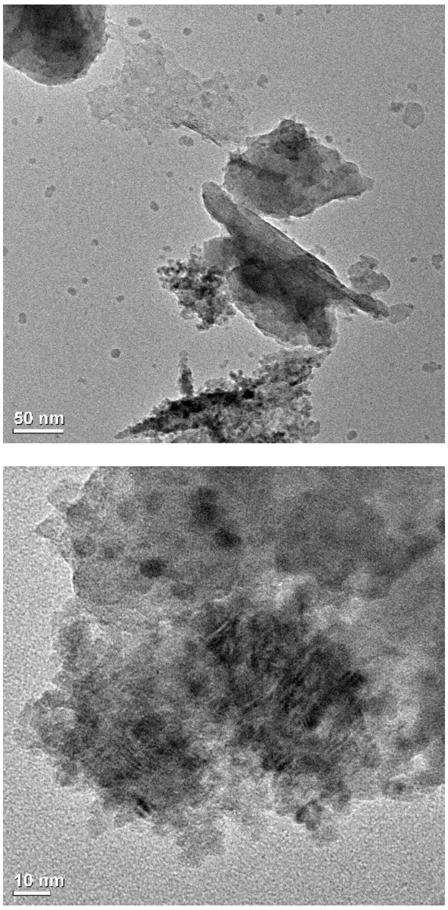

Fig. 6: HRTEM images of CDBE mediated CuO NP.

Table 1: MIC of biogenically synthesized CuO NP against bacterial strains.

Test Pathogen	MIC (µg/ml) of CuO NP	Control (Ampicillin)
B. subtilis	50	250
S. aureus	100	250
E. coli	50	100

Antibacterial Activity of CDBE Mediated CuO NP

The results of antibacterial performance of the CDBE mediated CuO NP are presented in Table 1. The antibacterial activity of the fabricated CuO NP was determined against three pathogens at different concentrations. CDBE mediated CuO NP demonstrated effectively potent and considerable antibacterial performance against *B. subtilis, S. aureus* and *E. coli* with ampicillin were used as a standard drug.

CONCLUSION

In summary of the achievements of this work, we successfully fabricated monoclinic CuO NP via facile biomimetic approach and CDBE is used as a green fuel. Analyses showed that the fabricated CuO NP was quasi-spherical and uneven in shape as observed in SEM and HRTEM analysis. The CDBE mediated CuO NP showed excellent bactericidal efficacy and hence it may be useful for the biomedical applications. The CuO NP fabricated using therapeutic plant extract may be implemented as a medical device in the future of nanomedicine.

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