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RESEARCH ARTICLE

PHYTOENGINEERED COPPER OXIDE NANOPARTICLES VIA TRIGONELLA FOENUM - GRAECUM: CHARACTERIZATION AND MULTIFUNCTIONAL POTENTIAL

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ABSTRACT

An aqueous preparation derived from fenugreek (Trigonella foenum-graecum) was investigated as a plant-based component in the preparation of copper oxide particles. The submitted account describes microwave treatment of a mixture containing fenugreek extract and a copper precursor, followed by drying and powder collection. Structural, spectroscopic and microscopic measurements were used to examine the recovered material. The reported absorption response was concentrated in the ultraviolet region, with a feature near 270–290 nm. Infrared bands suggested the presence of organic surface associated species, while diffraction reflections were assigned to monoclinic CuO (reference pattern JCPDS 48-1548); a Scherrer crystallite dimension of approximately 24 nm was reported. Electron micrographs showed irregular grains assembled into pronounced aggregates. Agar diffusion tests indicated inhibition of Escherichia coli and Staphylococcus sp., although the control identity and dose scheme require clarification. These observations support further investigation of fenugreek-assisted CuO preparation and its preliminary antibacterial response, subject to confirmation of the experimental protocol and reproducibility.

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INTRODUCTION

The performance of copper(II) oxide in functional materials depends not only on its bulk composition but also on the structural and chemical features introduced during preparation. CuO is a p-type semiconductor of interest in catalysis, environmental processes and antibacterial materials. In particulate samples, crystallite dimensions, defects, exposed surfaces and aggregation can all affect measurable properties. Consequently, synthesis conditions and characterization results need to be considered together rather than treating particle formation as an isolated step (1–5). Plant-assisted processing has been explored as a way to incorporate renewable organic constituents into the preparation of inorganic particles. Water-soluble metabolites may coordinate dissolved copper species and remain associated with the solid after isolation.

Their precise chemical role, however, cannot be established from a single spectrum: independent analyses are needed to distinguish surface adsorption, coordination and any proposed reduction pathway (6–8). Fenugreek is a widely available botanical source of diverse organic constituents, making its aqueous extract a practical medium for evaluating such interactions (8). Biological testing offers a separate measure of functional performance. For copper-containing materials, proposed antibacterial pathways include membrane interactions, copper release and oxidative stress, but a zone-of-inhibition assay by itself does not distinguish among these processes. The diffusion behaviour of particles and dissolved species, along with solvent controls and inoculation conditions, can influence the observed diameter (9–15). Thus, careful reporting of test concentration, applied volume, controls and replicate variability is essential.

This study examines fenugreek-assisted CuO material using optical absorption, infrared spectroscopy, X-ray diffraction and scanning electron microscopy. Preliminary agar diffusion measurements against E. coli and Staphylococcus sp. are discussed alongside the structural observations. The objective is to describe the experimentally observed material and its response without attributing unmeasured mechanisms to the sample.

MATERIALS AND METHODS

Starting materials: Fenugreek seeds, a copper salt and double-distilled water were used in the reported preparation.

Fenugreek extract: Seeds were washed, dried and milled before aqueous extraction. In the submitted manuscript, 0.5 g of powdered seeds was combined with 100 mL of double-distilled water and filtered through Whatman No. 1 paper.

Preparation of copper oxide material: The submitted manuscript states that 10 mL of 0.5% (w/v) fenugreek extract was mixed with 5 mL of 3 mM copper (II) nitrate solution. The mixture was exposed to 800 W microwave irradiation for 120 s, cooled, dried at 100 °C for 10 h and powdered.

Instrumental measurements: The report identifies X-ray diffraction using a Rigaku MiniFlex instrument, UV–visible diffuse-reflectance measurements with a Shimadzu UV-3600, FTIR using a Shimadzu IRAffinity-1 and SEM using a ZEISS system.

Antibacterial assay: The reported test used Mueller–Hinton agar and well diffusion against E. coli and Staphylococcus sp. The nanoparticle suspension was described as 10 mg mL^{-1}. After inoculation and sample application, inhibition diameters were recorded in millimetres.

RESULTS AND DISCUSSIONS

Optical behaviour of Green Synthesized CuO Nanoparticles

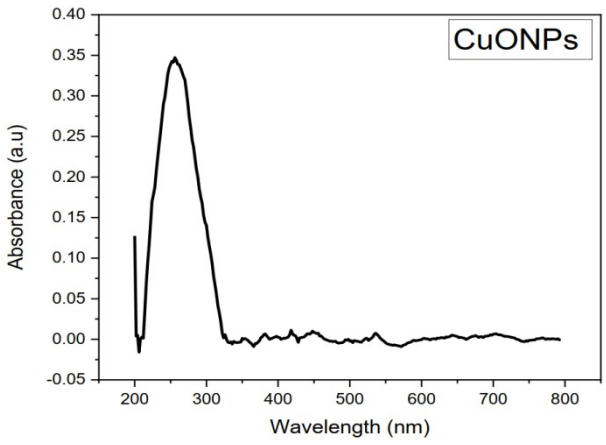


Figure 3.1. Optical absorption spectra of Green synthesized CuO Nanoparticles

The submitted spectrum is described as having its strongest response at short ultraviolet wavelengths, including a less intense feature in the vicinity of 270–290 nm, with comparatively little signal at longer wavelengths. This observation is compatible with an optically absorbing copper-containing product, but it is not sufficient by itself to establish its phase or purity. Residual extract constituents and scattering from aggregated particles may also affect the trace. Interpretation should therefore be based on the measured spectrum and corroborated with diffraction and chemical analysis (21).

FTIR Analysis of Green Synthesized CuO Nanoparticles: Reported FTIR maxima occurred near 3504, 2925, 2095, 1658, 1521, 1422, 1199 and 958 cm^{-1}. The high-frequency broad feature is consistent with O–H-containing species, while the 2925 cm^{-1} band may reflect aliphatic C–H groups. Signals in the 1658–1199 cm^{-1} region could arise from several overlapping organic vibrations; assignments should remain tentative without comparison to the extract spectrum. The 2095 cm^{-1} signal warrants special caution because its origin is uncertain. The listed spectrum does not by itself demonstrate Cu–O lattice modes, commonly assessed at lower wavenumbers. Consequently, these bands provide evidence of possible organic residues but not definitive proof of a specific capping mechanism (22).

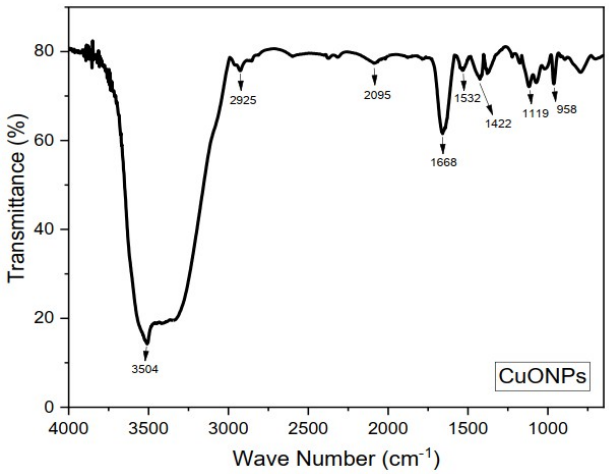


Figure 3.2. FTIR spectra of Green synthesized CuO Nanoparticles

X-ray Diffraction (XRD) Analysis of Green Synthesized CuO Nanoparticles

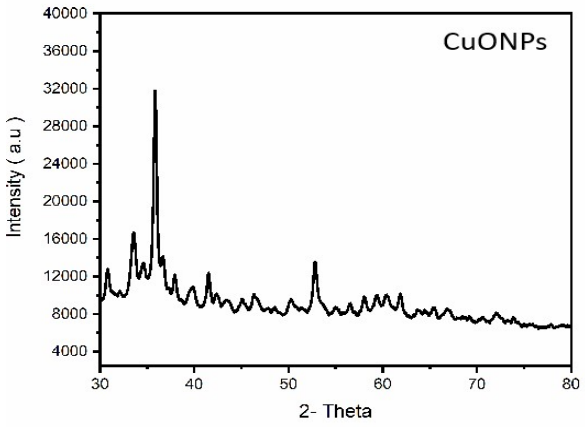


Figure.3.3. XRD pattern of Green Synthesized CuO Nanoparticles

Reflections were reported at approximately 2θ = 32.5°, 35.5°, 38.7°, 48.8°, 53.5°, 58.3°, 61.5°, 66.2°, 68.1°, 72.4° and 75.1°. The overall set was interpreted in relation to the monoclinic CuO reference pattern (JCPDS 48-1548). A reported crystallite

size of about 24 nm was obtained using the Scherrer approach. This is a coherent-domain estimate rather than an SEM particle diameter. Absence of conspicuous extra reflections within the measurement sensitivity supports the dominant CuO assignment but does not prove absolute phase purity (23).

SEM Analysis of Green Synthesized CuO Nanoparticles: The described micrographs show a non-uniform assembly of granular material. Smaller features occur alongside larger, compact clusters, and the surfaces appear uneven at the available magnifications. Such images indicate pronounced aggregation after processing, but they do not establish the size distribution of individual primary crystallites. The reported XRD crystallite estimate should therefore not be presented as a directly measured SEM particle size. Higher-resolution imaging with quantitative image analysis would be needed to assess primary-particle dimensions (24).

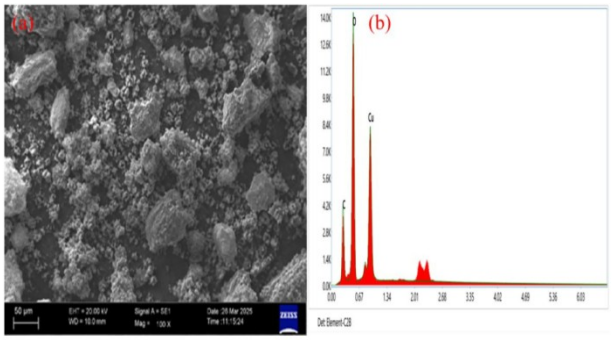


Figure 3.4 SEM EDX image of CuONPs

Table 1.1. Antibacterial activity against E. coli and Staphylococcus

Well No.	E. coli (mm)	Staphylococcus (mm)
1	13 (10µl)	13(10µl)
2	14 (12µl)	14 (12µl)
3	15 (13µl)	18 (16µl)
4	16 (15µl)	19 (17µl)
5	18 (16µl)	15 (13µl)
6	20 (20µl)	17 (15µl)
7 (centre)	22 (10µl)	22 (10µl)

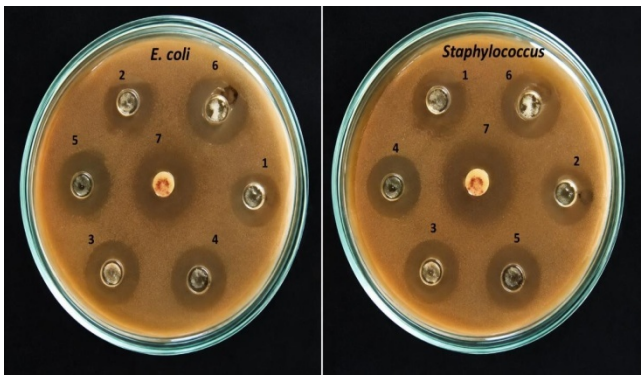


Figure. 3.5 (a) E. coli (1-10µl, 2-12µl, 3-13µl, 4-15µl, 5-16µl, 6-20µl, 7-10µl) and (b) Staphylococcus (1-10µl, 2-12µl, 3-16µl, 4-17µl, 5-13µl, 6-15µl, 7-10µl)

Anti – Bacterial Activity: In the submitted report, inhibition diameters against E. coli were said to range from 13 to 20 mm and those against Staphylococcus sp. from 13 to 19 mm. These observations suggest that the test material or associated diffusible species affected growth under the assay conditions. However, the report does not provide a consistent mapping of well volume to each diameter and states that the central well produced a 22 mm zone. The identity of this control and the sample-dose sequence must be checked before presenting a dose–response conclusion. Membrane damage, ion release and reactive oxygen species are possible hypotheses rather than mechanisms established by this assay (25).

CONCLUSION

The submitted measurements describe a fenugreek-assisted copper oxide material exhibiting ultraviolet absorption, infrared features attributable in part to organic constituents, diffraction reflections consistent with monoclinic CuO and a strongly aggregated granular morphology. A crystallite dimension of approximately 24 nm was reported from diffraction analysis, whereas primary particle sizes could not be established from the described SEM images. Preliminary well-diffusion observations indicated antibacterial responses against E. coli and Staphylococcus sp. The work provides a basis for more rigorous investigation, but its publication-ready interpretation depends on resolving the synthesis-method discrepancies, validating the inhibition-zone records and documenting reproducibility. Follow-up measurements of copper release, minimum inhibitory concentration and biological controls would strengthen the assessment of antimicrobial potential.

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