

Biosynthesis, Characterization, and Antifungal Activity of Copper Oxide Nanoparticles Using Myrtaceae Plant Extracts

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ABSTRACT

Copper oxide nanoparticles (CuO NPs) were biogenically synthesized using aqueous extracts from *Psidium guajava*, *Syzygium cumini*, and *Syzygium aromaticum*, which are all members of the Myrtaceae family. Characterization was performed utilizing UV-Vis, FTIR, XRD, and SEM-EDS, confirming the synthesis of nanoparticles. The CuO nanoparticles exhibited significant antifungal activity against *Candida albicans* using the agar well diffusion method. The extract of *Syzygium aromaticum*-mediated nanoparticles demonstrated the highest bioactivity.

Keywords: Green synthesis, CuO nanoparticles, Myrtaceae, *Candida albicans*.

I. INTRODUCTION

Nanotechnology is a thriving area in materials science, and with the unique physicochemical properties of metal and metal oxide nanoparticles, metal oxides are one type of material that has received the most attention in terms of studies. In particular, there have been many studies on copper oxide nanoparticles (CuO NPs) for their catalytic, optical, electrical, and biological roles [1,2]. In comparison to gold or silver, copper-based nanomaterials are abundant, low-cost and have shown to have great antimicrobial properties [3,4]. The green method of synthesizing nanoparticles, using biological sources to reduce and stabilize, is much more sustainable than traditional chemical or

physical methods that require harsh high temperatures, toxic solvents or solvents, or hazardous reducing agents [5].

Using biological sources to reduce and stabilize nanoparticles is more sustainable as plants as chemical reducing agents have additional co-factors that can act as both reducing and stabilizing agents. In many, plant-mediated processes allow for the production of functional nanoparticles with potential for commercial applications due to the rich biological content produced during the reduction which include the use of bioactive secondary metabolites containing, flavonoids, polyphenols, alkaloids, tannins, saponins, and terpenoids [6,7]. Members of the Myrtaceae family are a vast group of medicinal plants that have

historically been used in a number of ethnobotanical and traditional medicine cases.

Members of the Myrtaceae family such as *Psidium guajava* (Guava), *Syzygium cumini* (Jamun), *Eucalyptus globulus* (Eucalyptus), and *Syzygium aromaticum* (Clove), contain a number of phytoconstituents with some, eugenol, ellagic acid, anthocyanins, and quercetin, having the ability to assist with the formation of nanoparticles while improving their biological activity [8–10]. Copper can be found in numerous biological systems, primarily as a trace element, where it plays vital roles in a vast number of biological processes.

II. MATERIALS AND METHODS:

Copper sulfate pentahydrate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$) was purchased from Sigma-Aldrich Chemicals. All chemicals used were of analytical reagent grade and were not further purified. The leaves of *Psidium guajava*, *Syzygium cumini* were collected from the college campus, and *Syzygium aromaticum* (clove) was purchased at the local market. Ultrapure water was used for the extraction process.

Preparation of the aqueous extract: The leaves of *Psidium guajava*, *Syzygium cumini*, and *Eucalyptus globulus* were collected, washed with distilled water, air dried in the shade, and finely ground. The buds of *Syzygium aromaticum* (clove) were collected, washed with distilled water, and powdered using a mortar and pestle. For the extraction procedure, 10 grams of powdered material of each plant was transferred into 100 mL of ultrapure water and placed into a boiling water bath exposed to heat for 10 minutes. The resulting mixtures were filtered through Whatman filter paper No. 41.

Synthesis of copper nanoparticles: For the synthesis of CuO nanoparticles (CuO NPs), a 0.01 M copper sulfate pentahydrate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$) solution was prepared. Upon transferring the aqueous plant extract to 100 mL of the copper sulfate solution, the solution changed from blue to dark green, and confirmed the

production of the nanoparticles. The product solution was centrifuged for 15 minutes at 7000 rpm to collect the CuO nanoparticles.

III. RESULTS AND DISCUSSION:

UV-Visible Spectroscopy

The UV-Visible absorption spectra of synthesized CuO NPs obtained from the water extracts of *Psidium guajava*, *Syzygium cumini*, *Eucalyptus globulus*, and *Syzygium aromaticum* showed distinct bands between 260–337 nm that are characteristic of CuO nanoparticles. The broad absorbance peak near 330–340 nm obtained from the *Psidium guajava*- and *Syzygium cumini*-mediated CuO NPs indicates the physical phenomenon of surface plasmon resonance (SPR). This observation also confirms that the size of the NPs is at the nanoscale and crystalline [23]. For *Syzygium aromaticum*-derived NPs, the observed blue shift to shorter wavelengths (260–264 nm) indicates that these are smaller-sized NPs, conforming to the molecular physical importance of quantum confinement. The nature of the SPR bands varies from one material to another as the position and intensity is subject to how the NPs are manipulated regarding size, shape, agglomeration, dielectric nature of the medium used in the synthesis and the nature of the capping agents in the *Psidium guajava*, *Syzygium cumini*, and *Syzygium aromaticum* extracts [24,25]. The spectral attributes support the bio-reduction of Cu^{2+} to CuO NPs was successful, presumably carried out by the secondary metabolites including phenolics, flavonoids and terpenoids, which must be providing electrons and protecting the NPs from further agglomeration [26]. Additionally, there is no secondary absorption bands, indicates the obtained nanoparticles are pure with no secondary phases or unreacted precursors. The observed similarity in spectral behaviour supports the reproducibility of CuO NPs produced under green protocols that can be obtained [27].

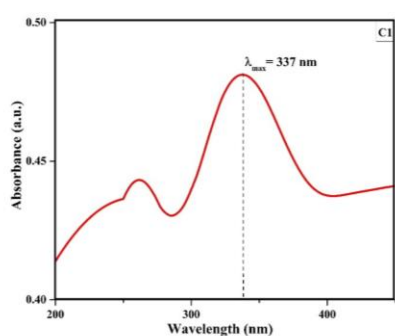


Fig a) UV-Visible of CuO from Psidium Gujava

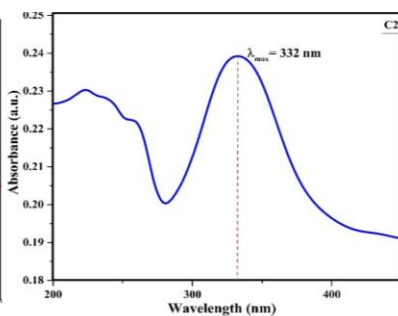


Fig b) UV-Visible of CuO from Syzium cumini

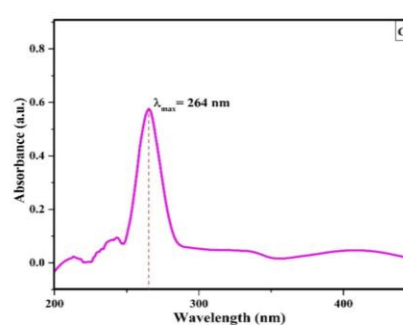
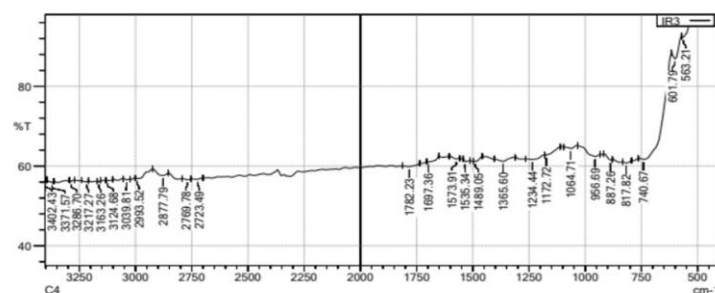
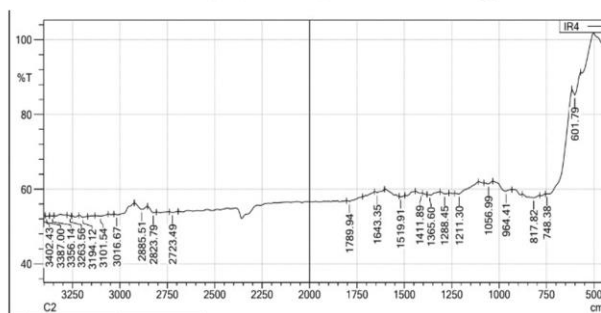
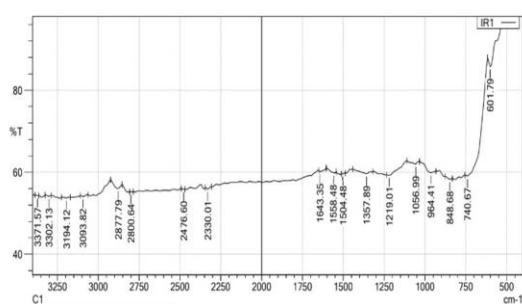


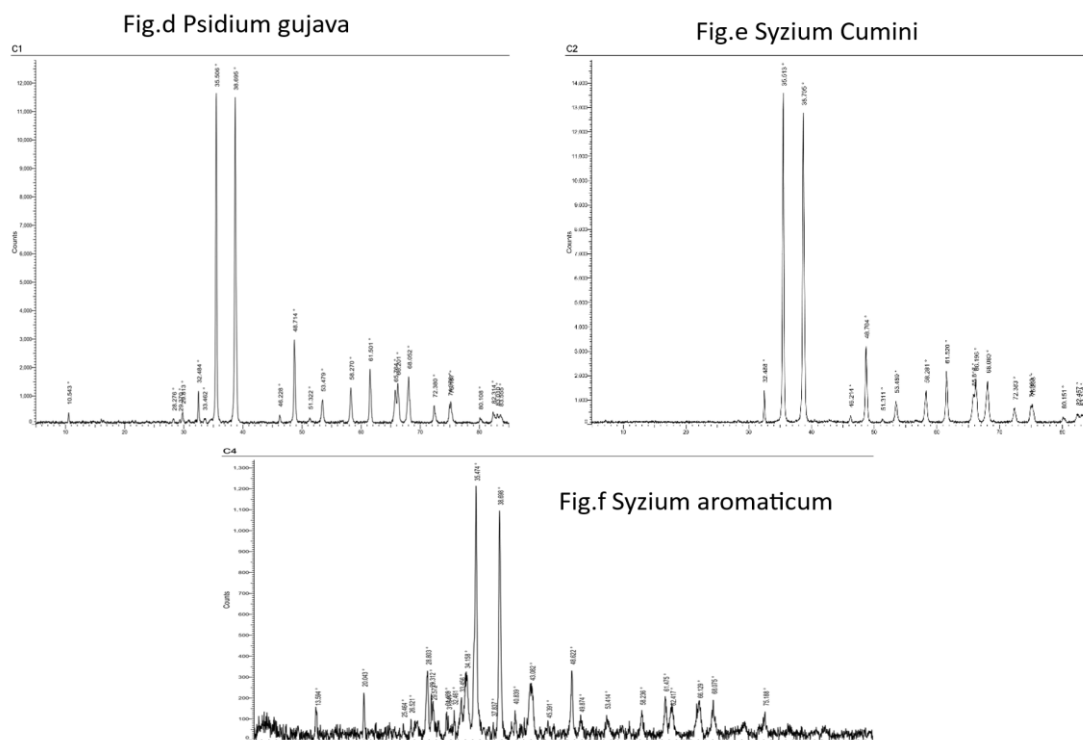
Fig a) UV-Visible of CuO from Syzium aromaticum

FTIR Analysis

FTIR spectroscopy provided an important understanding of the phytochemical interactions involved in the production and stabilization of CuO nanoparticles. The broad absorption band in the region of $3200\text{--}3400\text{ cm}^{-1}$ is most likely due to O–H and N–H stretching, and these absorptions are usually found in associations with hydroxyl groups in phenolics or amine groups in alkaloids and proteins. These functional groups can facilitate reducing and capping behaviour based on hydrogen bonding and redox potential[16,17]. The absorption peak around 1600 cm^{-1} corresponds to C=C stretching from the aromatic rings suggesting the flavonoids and polyphenols were involved in facilitating nanoparticle reduction and stabilization[18]. Absorption bands in

the $1200\text{--}1000\text{ cm}^{-1}$ range represent C–O and C–N stretching due to C–O and C–N bonds in ethers, esters and glycosidic bonds associated with the plant-derived secondary metabolites in glycosides and peptides[19]. A sharp peak at $\sim 601\text{ cm}^{-1}$ is also typically observed for Cu–O stretching and proves the successful formation of CuO nanoparticles. This absorption band is also in the metal–oxygen bonding fingerprint region previously reported in CuO syntheses[20,21]. All of the results presented here give continued evidence that plant phytochemicals are not only acting as bioreductants, but assisted by forming a natural stabilizing layer that envelopes the nanoparticles protecting against agglomeration, thereby enhancing dispersion[22].



XRD Analysis

XRD analysis of the CuO nanoparticles for Psidium guajava revealed sharp peaks at $2\theta = 35.506^\circ, 38.695^\circ, 48.714^\circ$ corresponds to crystal planes (200), (111) and (220) with particle size 65.78nm. Match with JCPDS card 96-721-2243. The intense peaks at 35.61° and 38.70° relate to the (002) and (111) crystal planes of monoclinic CuO. For Syzygium cumini with particle size 69.35nm. JCPDS card 96-153-5639. X-ray diffraction (XRD) of CuO nanoparticles prepared with the help of clove extract exhibited strong diffraction peaks at 2θ values of $35.47^\circ, 38.69^\circ, 48.62^\circ$ corresponding to (111), (111), (-202) monoclinic phase of CuO, JCPDS No. 96-152-6991 with particle size 52.44nm.

SEM-EDS Analysis.

The **surface morphology and elemental composition** of the biosynthesized copper oxide nanoparticles (CuO NPs) were examined using **scanning electron microscopy (SEM)** coupled with **energy dispersive X-ray spectroscopy (EDS)**.

SEM Analysis.

SEM micrographs evidenced that the CuO NPs synthesized with different Myrtaceae plant extracts showed mainly spherical and some irregular morphologies. The surfaces of the particles appeared aggregated most likely due to the drying and calcination process; however, the individual nanoparticles were fairly well distributed and small in size (50–70 nm). The differences in morphology among samples can be explained by the variation in nature and concentration of phytochemicals in extract. For example, polyphenols, flavonoids, and terpenoids produce stabilizing effects, which accentuate particle shape and surface [28,29]. The NPs produced using the Syzygium aromaticum showed to have more uniformity and compactness, likely due to the concentration of eugenol for efficient capping. The fact that we did not produce large agglomerates is strong validation that the biosynthetic method was effective in producing stabilized nanoparticles thus enhancing their surface reactivity and dispersion.

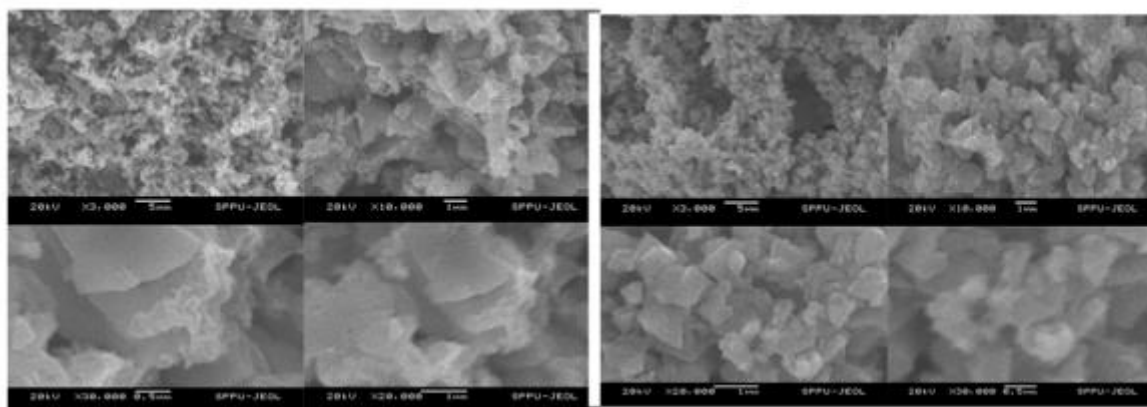


Fig.g SEM for Psidium guajava

Fig.h SEM for syzium cumini

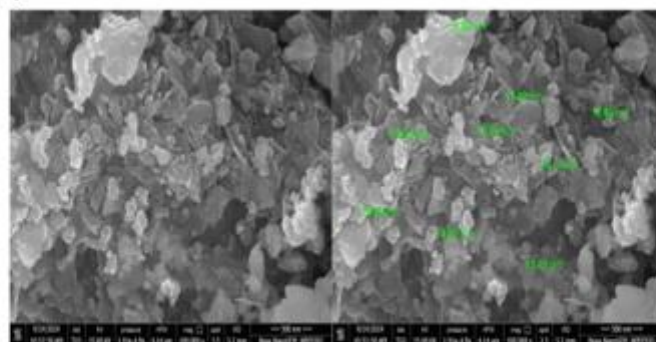


Fig.i SEM Syzium aromaticum

EDS Analysis:

The elemental composition of the synthesized nanoparticles was identified using EDS spectra. Strong peaks of the elements copper (Cu) and oxygen (O) demonstrated that CuO nanoparticles had been formed. Both copper peaks are observed at energy levels near 0.9 keV and 8.0 keV, while oxygen signals

were near 0.5 keV in line with previous studies of CuO nanostructures [30]. The signals of trace carbon were likely due to residual plant biomolecules or the carbon coat for the sample holder. The absence of any impurity elements provides further support for the purity and efficacy of the green synthesis method.

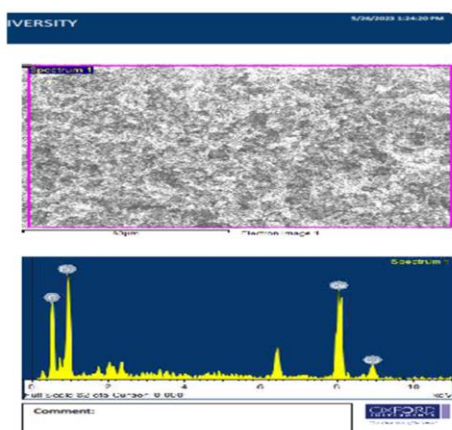


Fig.j EDS for Psidium guajava

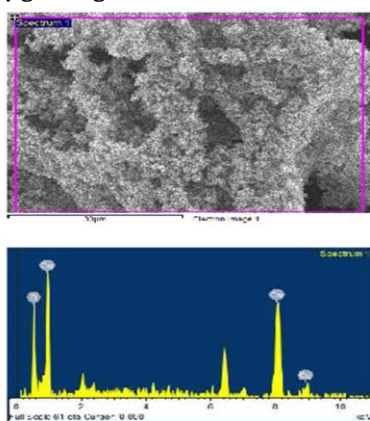


Fig.j SEM for syzium cumini

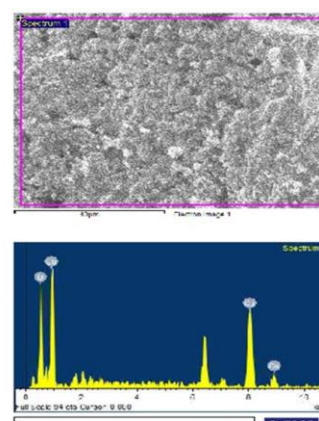


Fig.k SEM Syzium aromaticum

Antifungal Activity:

The antifungal activity of biosynthesized copper oxide nanoparticles (CuO NPs) against *Candida albicans*, a

clinically relevant fungal pathogen that causes mucosal and systemic infection, was evaluated. All CuO NP samples exhibited measurable inhibition

zones using the agar well diffusion method. The nanoparticles derived from *Syzygium aromaticum* were the most active (mean zone: 21.75 mm), followed by the CuO NPs mediated by *Psidium guajava* extract.

Sr.No.	Sample	Zone of inhibition			
		mg sample	μ L DMSO	Candida albican in mm	Mean (mm)
1	Copper	10	01	16,20,17,20	18.25
2	Sulphur	10	01	16,16,15,17	16
3	Manganese	10	01	-,-,-,-	-
4	Itracozone Flucazone	10	01	18,16,17,16 18,19,21,20	16.75 19.5



IV. CONCLUSION:

The research shows that plant extract from the Myrtaceae family, are effective bioreductants and stabilizers in synthesizing CuO nanoparticles. CuO NPs derived from *Syzygium aromaticum* showed the highest antifungal activity of all the plant extracts included in this study suggesting that the CuO NPs have promising potential in pharmaceutical and agricultural sectors.

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REFERENCES

- [1]. Sharma, V.K. et al., Adv. Colloid Interface Sci., 145(1–2), 83–96 (2009).
- [2]. Nasrollahzadeh, M. et al., J. Mol. Liq., 253, 228–232 (2018).
- [3]. Theivasanthi, T., Alagar, M., Nano Biomed. Eng., 4(2), 58–65 (2012).
- [4]. El-Naggar, M.E. et al., Sci. Rep., 7, 13043 (2017).
- [5]. Irvani, S., Green Chem., 13(10), 2638–2650 (2011).
- [6]. Mittal, A.K. et al., Biotechnol. Adv., 31(2), 346–356 (2013).
- [7]. Raghunandan, D. et al., Colloids Surf. B Biointerfaces, 105, 342–346 (2013).
- [8]. Cortes-Rojas, D.F. et al., Asian Pac. J. Trop. Biomed., 4(2), 90–96 (2014).
- [9]. Chandra, H. et al., Environ. Nanotechnol. Monit. Manag., 9(4), 523 (2019).
- [10]. Javed, R. et al., Arab. J. Chem., 14(1), 102924 (2021).
- [11]. Hajipour, M.J. et al., TrAC Trends Anal. Chem., 30(10), 1585–1598 (2011).
- [12]. Ruparelia, J.P. et al., Acta Biomater., 4(3), 707–716 (2008).
- [13]. Jain, D. et al., Dig. J. Nanomater. Biostruct., 4(3), 557–563 (2009).
- [14]. Prabhu, S., Poulse, E.K., Int. Nano Lett., 2, 32 (2012).
- [15]. Alavi, M., Karimi, N., Biometals, 34(3), 437–453 (2021).
- [16]. Huang, J. et al., Colloids Surf. A Physicochem. Eng. Asp., 371(1–3), 122–126 (2010).
- [17]. Awwad, A.M. et al., Green Sustain. Chem., 2(3), 141–147 (2012).
- [18]. Song, J.Y., Kim, B.S., Bioprocess Biosyst. Eng., 32(1), 79–84 (2009).

- [19]. Sathishkumar, M. et al., Colloids Surf. B Biointerfaces, 88(1), 334–339 (2011).
- [20]. Gharagozlou, M., J. Alloys Compd., 491(1–2), 484–487 (2010).
- [21]. Ramesh, P.S. et al., Dig. J. Nanomater. Biostruct., 7(3), 1311–1319 (2012).
- [22]. Barabadi, H. et al., Artif. Cells Nanomed. Biotechnol., 46(sup3), S1047–S1058 (2018).
- [23]. Renugadevi, K. et al., Mater. Today: Proc., 33, 3548–3554 (2020).
- [24]. Prasad, K.S. et al., Spectrochim. Acta A Mol. Biomol. Spectrosc., 91, 293–297 (2012).
- [25]. Ahmed, S. et al., Nanotechnol. Sci. Appl., 9, 1–16 (2016).
- [26]. Khatoon, N. et al., Adv. Nat. Sci. Nanosci. Nanotechnol., 8, 045014 (2017).
- [27]. Baral, A. et al., J. Saudi Chem. Soc., 25(6), 101307 (2021).
- [28]. Ramesh, M. et al., J. Photochem. Photobiol. B, 173, 43–49 (2017).
- [29]. Singh, J. et al., Artif. Cells Nanomed. Biotechnol., 44(1), 1569–1577 (2016).
- [30]. Verma, S. et al., Appl. Nanosci., 8(6), 1639–1646 (2018).