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Copper Nanoparticles Phytofabrication by Utilizing *Brassica oleracea* var. *gemmifera* and Exploring their Potential as Antioxidant and Antibacterial Agents

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Abstract:- The study aimed to synthesize copper nanoparticles (CuNPs) using *Brassica oleracea var. gemmifera* extract (BOE) and investigate their antioxidant and antibacterial properties. The BOE-mediated CuNPs (BOE-CuNPs) were successfully synthesized utilizing reducing and stabilizing properties of *B. oleracea var. gemmifera* extract. The nanotechnology features showed that BOE-CuNPs were nano in size (106.59 ± 4.77 nm), slightly agglomerated, stable (-12.41 ± 1.88 mV), and made up of mainly copper. The green synthesized BOE-CuNPs have potential antioxidant features and have EC_{50} values (concentration essential to inhibit 50% of free radicals) of 334.09 ± 17.70 µg/mL and 361.43 ± 12.91 µg/mL in DPPH and ABTS free radical scavenging activity, correspondingly, and could be useful in treating oxidative-stress-mediated conditions. Also, as-synthesized BOE-CuNPs have potential antibacterial activity and showed the highest antibacterial activity against *Escherichia coli* – MTCC 41 and *Listeria monocytogenes* – MTCC 657, and could be useful as an antibacterial representative in the biomedical field. However, to utilize BOE-CuNPs, an in-detailed functional and toxicological profile of BOE-CuNPs needs to be performed.

Keywords:- *Copper Nanoparticles, Brassica oleracea var. gemmifera, Green Synthesis, Antioxidant Activity, Antibacterial Activity.*

I. INTRODUCTION

The manipulation of atoms and molecules, or "nanotechnology," is a rapidly developing discipline of study that has shown enormous promise across many scientific domains. Nanotechnology works with particles with diameters ranging from 1 to 100 nm. The small size and large surface area of these particles eventually lead to an increase in the state of activity. A wide range of biomedical and pharmaceutical fields, including immunology, bioremediation (environmental applications), cardiology, diagnostics, biomarkers, genetic engineering, antibacterial, anticancer, bio-imaging, cosmetics, water treatments, antibacterial, anticancer, and energy production, can benefit from the use of NPs (Emerich & Thanos, 2003).

Silver (Ag), platinum (Pt), nickel (Ni), iron (Fe), gold (Au), palladium (Pd), cobalt (Co), and copper (Cu), as well as their oxidized forms, such as Fe_3O_4, ZnO, and CuO, are among the metals that are most commonly used for the synthesis of NPs. Because of its natural occurrence in biological structures, antibacterial qualities, low toxicity, and greater cost-effectiveness compared to Au, Ag, and Cu has emerged as a metal of interest from this list (McNeil, 2005).

The "green" production of metal/oxide NPs has drawn a lot of interest in materials science as a dependable, environmentally acceptable, and sustainable process. The use of CuNPs in a variety of disciplines has drawn a lot of attention. It has been discovered that a variety of organisms, including bacteria, fungi, algae, and plants, are able to produce copper NPs. Plant extract is made up of active ingredients extracted from various plant components, including bark, leaves, fruits, shoots, flowers, roots, and seeds. These compounds serve as stabilizing and reducing agents during the bio-reduction of metal ions to synthesize new metal NPs. Reducing phytochemicals have been identified in the literature as alkaloids, polysaccharides, sugar compounds, aromatic amines, acidic compounds, phyto-proteins, phenolic compounds, flavonoids, and several other components of the plant extract. These plant extracts may include beneficial phytochemicals that boost the effectiveness of the NPs' defenses against microbial pathogens and malignant cells. According to every scientific study, CuNPs have special qualities, including fungicidal, antibacterial, anticancer, and catalytic natural action against harmful dye deprivation (Waris *et al.,* 2021).

This study evaluates and offers the possible uses of *Brassica oleracea* var. *gemmifera* (Brussels sprouts) extract-mediated synthesis of CuNPs in an environmentally friendly way. *B. oleracea* is grown for fodder, vegetables, and aesthetic purposes. It is among the world's oldest crops. The majority of *B. oleracea* cultivars are used as vegetables and fodder plants. In addition, cabbage is grown for its therapeutic qualities. These include, among other things, the treatment of kidney stones, gastrointestinal tract inflammation and catarrh, and a number of respiratory illnesses because of the antibacterial qualities of phytotherapy. Numerous studies have verified *B. oleracea*'s anticancer activity, which is believed to be caused by the plant's abundance of aliphatic and aromatic glucosinolates. It is a significant research object because of these qualities (Rakow, 2004).

Green-CuNPs production is both environmentally and commercially advantageous. Biomedicine, synthetic medications, bioremediation, molecular engineering, bioengineering, gene introduction and modifications, dye degradation, catalysis, cosmetics, and textiles are just a few of the industries that use CuNPs. CuNPs' structural characteristics and biological impacts show promise for the life sciences (Harishchandra *et al.,* 2020).

The present study analyses and proposes sustainable applications for the synthesis of CuNPs mediated by *Brassica oleracea* var. *gemmifera* (Brussels sprouts) extract. The as-synthesized CuNPs were characterized using nanotechnology techniques to ensure their diverse bio-potentials. Subsequent research focused on revealing that CuNPs possessed antibacterial and antioxidant qualities.

II. MATERIALS AND METHODS

A. *Chemicals and Reagents*

Potassium persulfate, deionized water, 2,2-diphenylpicrylhydrazyl (DPPH), ethanol, methanol, and 2,2-azinobis (3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) were obtained from Merck, India. Mueller-Hinton media, nutrient media, Zonescale, and sodium chloride were obtained from HiMedia, Mumbai, India. Deionized water, copper sulfate, ethanol, methanol, and other reagents used in the study were obtained from Merck, India. The plasticware was obtained from Tarsons Products, India. The glassware used for the experiments was waterlogged with 5% hypochlorite solution, cleaned with soap and distilled water, and then dehydrated at 70 °C in a chamber equipped with hot air equipment.

B. *Plant Material Collection and Preparation of Extract*

Brussels sprouts (*Brassica oleracea* var. *gemmifera*) were collected from the local agriculture marketplace, Guntur, Andhra Pradesh, India, and were used in this study. The identification of the specimens was confirmed, and the specimens were thoroughly washed with deionized water and shade-dried for two weeks at 25 °C. After 500 g of dried leaves were ground into a powder with a blender and sieved through a fine mesh screen (US standard mesh number 70), the extract was obtained by cold maceration with ethanol (Wu *et al.,* 2015). Following filtration through Whatman No. 1 filter paper, the resulting *B. oleracea* var. *gemmifera* extract (BOE) was vacuum-bagged and maintained at -20 °C in the dark for consequent green preparation of copper NPs.

C. *Green Synthesis of Copper Nanoparticles*

Briefly, 10 mL of deionized water was mixed with 100 mg of *B. oleracea* var. *gemmifera* extract (BOE). Next, 10 mL of this extract suspension was mixed with a 40 mL solution containing five mM copper sulfate solution and pH adjusted to 7.0. The color development of the reaction was regularly observed when this mixture was added. As copper nanoparticles (CuNPs) were developed, the solution's color changed to green. The resulting solution was centrifuged for 30 min at 15,000 rpm at 4 °C. After that, a second centrifugation was performed using deionized water to clean out the BOE-mediated synthesized CuNPs (BOE-CuNPs) for 10 min at 15,000 rpm at 4 °C. Five times through this washing process, the unreacted material was eliminated. The obtained pure BOE-CuNPs were subjected to evaporation to remove water content and were powdered (Wu *et al.*, 2020). As-synthesized BOE-CuNPs were used for further characterization and biological functions.

D. *Physicochemical Attributes of Copper Nanoparticles*

The optical properties of BOE-CuNPs were measured at room temperature using a UV-Vis spectrophotometer (Shimadzu, Japan). Zeta potential and dynamic light scattering (DLS) measurements of BOE-CuNPs were performed with a Zetasizer Nano ZS (Malvern Panalytical). An energy-dispersive X-ray (EDX) unit on a scanning electron microscope (SEM) (Icon Analytical, Quanta 250, FEI, USA) was used to examine the morphology, particle size, and elemental content of BOE-CuNPs. The SEM pictures were captured with a 15 kV acceleration voltage. To prevent charge during SEM/EDX analysis, a small layer of gold was applied to BOE-CuNPs. The particle size of BOE-CuNPs from SEM images was measured using ImageJ software. The BOE-CuNPs were drop cast onto a pristine glassy carbon plate for SEM measurements, and it was then dried before imaging (Lin *et al.*, 2008; Sankar *et al.,* 2013; Faraji *et al.*, 2021; Verma & Das, 2021).

E. *Antioxidant Activity of Copper Nanoparticles*

➢ *DPPH Free Radical Scavenging Potential Assay*

Using a slightly modified version of Moskvin et al.'s (2020) approach, the antioxidant potential of BOE-CuNPs was assessed colorimetrically by the DPPH free radical scavenging potential assay. In short, a mixture of ethanol (1.2 mL) and different concentrations of BOE-CuNPs (up to 200 µg/mL) was added to a 2 mL Eppendorf tube containing 0.1 mM ethanolic DPPH solution (0.6 mL). The mixture was shaken for one minute using a vortex shaker (800 rpm), and the reaction was allowed to progress in darkness for 30 min at room temperature. DPPH solution without BOE-CuNPs was used as a control. The standard antioxidant used in the study was ascorbic acid. Following the incubation period, using a Synergy H1 plate reader (BioTek, USA) against ethanol, the absorbance of the samples was recorded at 517 nm. The DPPH free radical scavenging capacity of BOE-CuNPs was considered using the following formula:

$$\text{DPPH free radicals (\%)} = \frac{C_A - T_A}{C_A} \times 100$$

Where C_A stands for the control sample's absorbance. The absorbance of the test sample is indicated by the T_A.

The potential DPPH radical scavenging activity of BOE-CuNPs is expressed using the EC_{50} value, which defines the concentration of BOE-CuNPs at which 50% of the DPPH free radicals are scavenged.

➢ *ABTS Free Radical Scavenging Potential Assay*

Using a slightly modified version of the Gullon *et al.*, (2015) approach, the antioxidant potential of BOE-CuNPs was assessed colorimetrically by the ABTS free radical scavenging potential assay. Briefly, potassium persulfate (2.45 mM) and an aqueous ABTS solution (7 mM) were reacted for 16 hours in the dark to produce the ABTS solution. After diluting the ABTS solution to 0.70 ± 0.02 at 734 nm, it was added to the BOE-CuNPs (up to 200 µg/mL) and allowed to react for 12 minutes. The ABTS solution without BOE-CuNPs was referred to as the control. The standard antioxidant used in the study was ascorbic acid. Following the incubation period, the absorbance value was determined using a Synergy H1 plate reader (BioTek, USA) against ethanol at 734 nm. The ABTS free radical scavenging capacity of BOE-CuNPs was considered using the following formula:

$$\text{ABTS free radicals (\%)} = \frac{C_A - T_A}{C_A} \text{ x } 100$$

Where C_A stands for the control sample's absorbance. The absorbance of the test sample is indicated by the T_A.

The potential for BOE-CuNPs's ABTS radical scavenging activity is expressed using the EC_{50} value, which defines the concentration of BOE-CuNPs at which 50% of the ABTS free radicals are scavenged.

F. Antibacterial Activity of Copper Nanoparticles

The broad-spectrum antibacterial activity of BOE-CuNPs was tested using Gram-ve and Gram+ve bacterial pathogens. From the Microbial Type Culture Collection and Gene Bank (MTCC), which is based in India, the bacterial strains *Listeria monocytogenes* – MTCC 657, *Escherichia coli* – MTCC 41, *Pseudomonas aeruginosa* – MTCC 741, *Staphylococcus aureus* – ATCC 13565, *Enterococcus faecalis* – MTCC 439, *Klebsiella pneumoniae* – ATCC 13883, and *S. aureus* – ATCC 14458.

Using a well-diffusion (zone of inhibition) experiment, the antibacterial activity of BOE-CuNPs was assessed against bacterial pathogens. A lawn of the overnight-grown bacterial suspension (0.5 McFarland's) was swabbed over the solidified agar medium of Mueller-Hinton agar plates. Wells were made using a sterile cork borer with a 5-mm diameter. BOE-CuNPs at various doses (100 and 200 µg/well) were distinctly loaded into the wells. The Petri plates were incubated for 24 hours at 37 °C in an aerobic environment. Following incubation, the Petri plates were inspected to see the formation of inhibition zones surrounding the wells, which would have indicated that BOE-CuNPs had antimicrobial action against bacterial pathogens. The positive control was streptomycin. The outcomes (growth inhibition zones) were assessed using a Zonescale, and the average scores were recorded in mm (Vamshi *et al.*, 2023).

G. Statistical Analysis

There were three replicates of each experiment run, which was performed independently. The data were expressed as the mean ± standard deviation and subjected to one-way analysis of variance (ANOVA).

III. RESULTS AND DISCUSSION

A. Green Synthesis of Copper Nanoparticles

The primary indicator of BOE-CuNPs output is the color shift to a green that occurs when BOE is added to an aqueous copper sulfate solution. The color shift was caused by an interaction between incoming photons and the conduction electrons of metal nanoparticles (Jana *et al.*, 2016; Turakhia *et al.*, 2020). The formed BOE-CuNPs mixture was centrifuged at 15,000 rpm for 30 minutes at 4 °C. The BOE-CuNPs were subsequently washed out using a second centrifugation that took place for 10 minutes at 15,000 rpm and 4 °C using deionized water. The substance that had not reacted was removed after five washings. After evaporating the pure BOE-CuNPs to eliminate any remaining water, they were powdered. Further, characterization of as-synthesized BOE-CuNPs were investigated.

B. Characterization of Copper Nanoparticles

UV-vis is a widely used technique for characterizing nanoparticles. Surface Plasmon Resonance (SPR) measurement is used in this method to confirm the nanoparticle formation. This technique can be used to determine the NPs' size, stability, and aggregation. Usually, wavelengths between 200 and 700 nm are used to characterize metal and metal oxide nanoparticles (Faraji *et al.*, 2021; Verma & Das, 2021)

In our study, the synthesis of BOE-CuNPs was confirmed by a distinctive peak measured at 273 nm (**Fig. 1**). In this work, UV–vis spectroscopy was used to evaluate the impact of pH 7 on the reduction of copper sulfate into BOE-CuNPs. The ionization of the phenolic and flavonoid groups in the BOE may cause the prominent absorbance peak perceived at a neutral pH. As particle size increased, the peak value progressively dropped (Martínez-Castañon *et al.*, 2008). According to the results of this experiment, the ideal pH for reducing Cu^{2+} ions into BOE-CuNPs is 7.0. In support of our outcome, Mali *et al.*, (2020) have green synthesis of CuNPs using *Celastrus paniculatus* Willd. leaf extract and reported confirmed by a characteristic peak obtained at 269 nm.

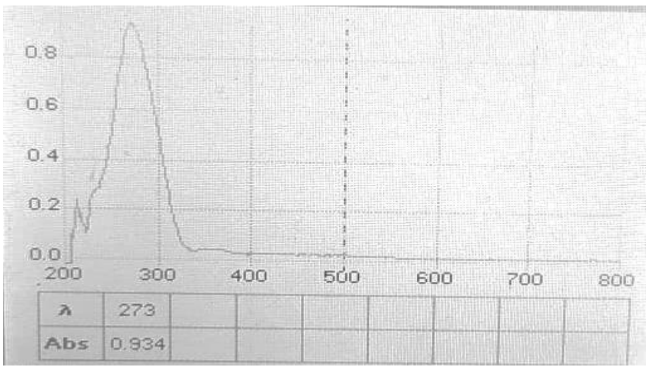

Fig 1 UV–Visible Spectrum of Green Synthesized *Brassica oleracea* var. *gemmifera* Extract-Mediated Copper Nanoparticles.

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Zetasizer Nano ZS (Malvern Panalytical) analysis was used to determine the average particle size of the BOE-CuNPs in the colloidal solution. The average particle size distribution of green synthesized BOE-CuNPs was found to be 106.59 ± 4.77 nm in **Figure 2.** BOE-CuNPs' increased size was attributed to their measured dimensions, which included biomolecules of BOE and a film of water covering their surface (Bhakya *et al.*, 2016). It was proposed that the biological property of BOE-CuNPs was increased or encouraged by the size of the synthesized BOE-CuNPs (Sankar *et al.*, 2014). In support of our outcome, green synthesised CuNPs with an average particle size distribution of 290 nm were produced by Malai *et al.*, (2020) and provided a reason that CuNPs' increased size was attributed to biomolecules of plant extracts and a film of water covering their surface of CuNPs.

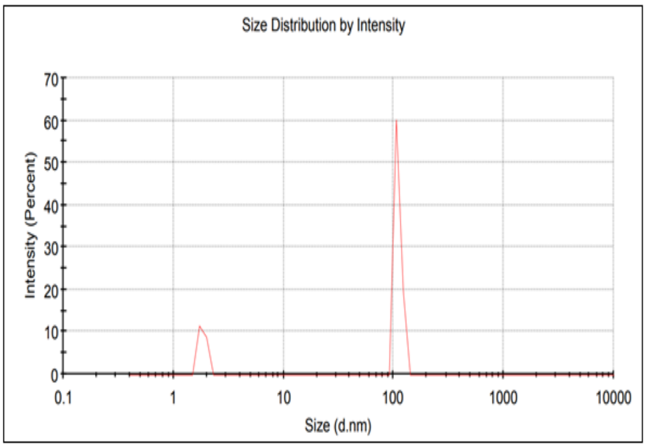

Fig 2 Dynamic Light Scattering Pattern of Green Synthesized *Brassica oleracea* var. *gemmifera* Extract-Mediated Copper Nanoparticles.

The surface charge of the BOE-CuNPs was determined via the Zetasizer Nano ZS (Malvern Panalytical) apparatus in the colloidal solution (Lin *et al.*, 2008; Sankar *et al.*, 2013). The current investigation revealed a negative zeta potential of -12.41 mV and a zeta deviation of 1.88 mV (**Fig. 3**). Agglomeration is inhibited, and a high negative value of zeta potential indicates a robust repelling force between the BOE-CuNPs particles. BOE-CuNPs had a polydispersity index value of 1.110. It was proposed that the biological property of BOE-CuNPs was increased or encouraged by the charge distribution of the synthesized NPs (Sankar *et al.*, 2014).

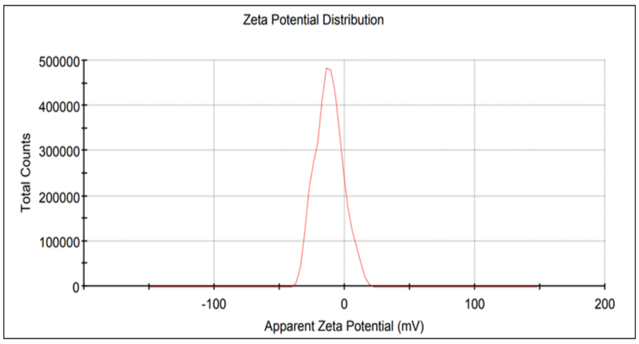

Fig 3 Zeta Potential of Green Synthesized *Brassica oleracea* var. *gemmifera* Extract-Mediated Copper Nanoparticles.

BOE-CuNPs were morphologically characterized by means of SEM investigation. Spherical particles of BOE-CuNPs with some agglomeration as a result of sample preparation were found in SEM analysis (**Fig. 4**). According to the size distribution analysis from ImageJ software, the BOE-CuNPs particles' average diameter was found to be 32.61 ± 3.07 nm.

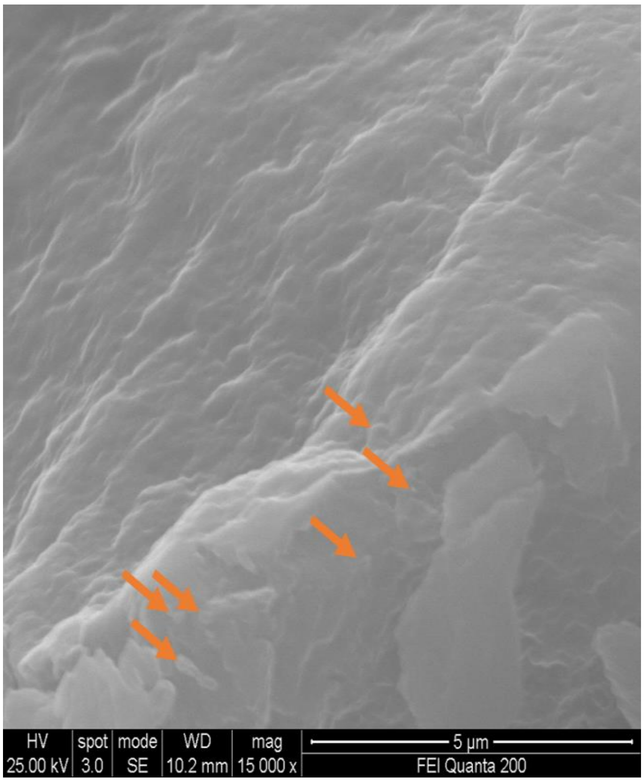

Fig 4 Scanning Electron Microscope Image of Green Synthesized *Brassica oleracea* var. *gemmifera* Extract-Mediated Copper nanoparticles.

The SEM-EDX studies validated the stability and composition of the produced BOE-CuNPs. After the BOE-CuNPs particles' purity levels were checked, it was discovered that *Brassica oleracea* var. *gemmifera* extract-mediated BOE-CuNPs had 72.89 percent Cu and a few faint signs of the elements and C, S, O, Ca, and Zn (**Table 1**). The X-ray emission from macromolecules such as proteins, polysaccharides, glycosides, steroids, flavonoids, phenolics, and tannins compounds that are present in the extracts could be the cause of these faint signals of C, S, O, Ca, and Zn (Mali *et al.*, 2020).

Table 1 Elemental Composition of Green Synthesized *Brassica oleracea* var. *gemmifera* Extract-Mediated Copper Nanoparticles (BOE-CuNPs) Determined by Scanning Electron Microscope-Energy-Dispersive X-ray Analysis

S. No	Element	Composition (%)
1	Cu	72.89
2	C	9.27
3	S	9.34
4	O	2.70
5	Ca	1.81
6	Zn	1.02
	Total	97.03

C. Antioxidant Activity of Copper Nanoparticles

The antioxidant activity of the as-synthesized BOE-CuNPs was assessed by the DPPH free radical scavenging test. The findings of the dose-dependent analysis of BOE-CuNPs's DPPH antioxidant activity are shown in **Figure 5.** The DPPH results showed that the BOE-CuNPs have dose-dependent free radical scavenging activity. The concentration of BOE-CuNPs at which 50% of the DPPH free radicals are scavenged (defined as EC_{50} value) was determined to be 334.09 ± 17.70 µg/mL. In support of our study, Wu *et al.*, (2020) green synthesized CuNPs using *Cissus vitiginea* and demonstrated their antioxidant activity by DPPH assay.

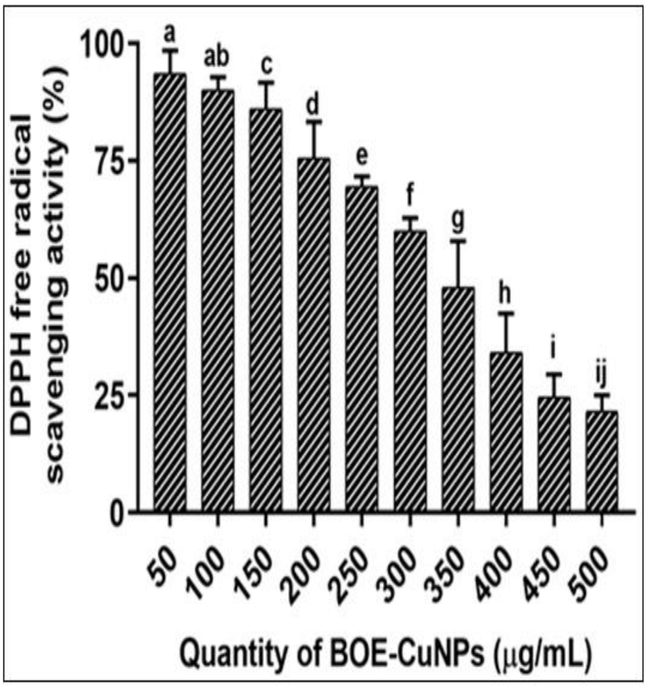

Fig 5 Dose-Dependent DPPH Free Radical Scavenging Activity of *Brassica oleracea* var. *gemmifera* Extract-Mediated Synthesized Copper Nanoparticles (BOE-CuNPs). Tukey's Test was used to Compare the Data at a Significance Level of 5%. Bar Graphs Displaying Distinct Alphabets Indicate Statistical Significance within the Specific Research Group.

The as-synthesized BOE-CuNPs' antioxidant capacity was evaluated using the ABTS free radical scavenging test. **Figure 6** displays the results of the ABTS antioxidant activity of BOE-CuNPs dose-dependently. The BOE-CuNPs' ability to scavenge free radicals in a dose-dependent manner was demonstrated by the ABTS data. A quantity of 361.43 ± 12.91 µg/mL was found to be the concentration of BOE-CuNPs at which 50% of the ABTS free radicals are scavenged, also known as the EC_{50} value. In support of our report, Kirubakaran *et al.*, (2023) green synthesized CuNPs using *Strobilanthes cordifolia* leaf extract and demonstrated their potential *in-vitro* antioxidant potential.

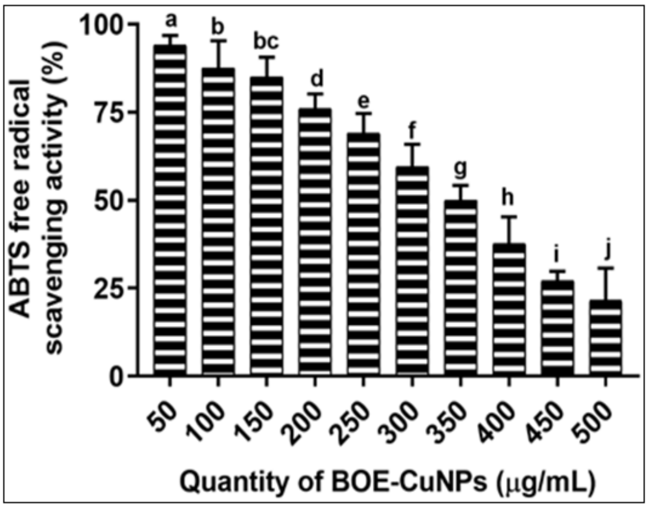

Fig 6 Dose-Dependent ABTS Free Radical Scavenging Activity of *Brassica oleracea* var. *gemmifera* Extract-Mediated Synthesized Copper Nanoparticles (BOE-CuNPs). Tukey's Test was used to Compare the Data at a Significance Level of 5%. Bar Graphs Displaying Distinct Alphabets Indicate Statistical Significance within the Specific Research Group.

The as-synthesized BOE-CuNPs offered superior antioxidant potential in the DPPH assay related to the ABT assay. In the present study, BOE was found to contain abundant polyphenols and other secondary metabolites and is linked to BOE-CuNPs. These polyphenols and other secondary metabolites might be responsible for BOE-CuNPs' antioxidant activity, which could be useful to the discovery of a fresh approach to improving oxidative-stress-mediated disorders and treating incurable diseases like cancer (Wu *et al.*, 2020).

D. Antibacterial Activity of Copper Nanoparticles

In this investigation, the zone of inhibition experiment was utilized to examine the antibacterial activity of BOE-CuNPs against bacteria qualitatively. The zone of inhibition against the studied microorganisms supported the results, which suggested that BOE-CuNPs could possess antibacterial potential. It was discovered that the degree of the zone of inhibition against the BOE-CuNPs was dose-dependent; at lower BOE-CuNPs concentrations, the zone of inhibition was found to be smaller, while at higher BOE-CuNPs concentrations, it was found to be higher. **Table 2** displays the study's findings. In the study, BOE-CuNPs had the highest zone of inhibition, which means potential antibacterial activity towards *E. coli* – MTCC 41 and followed by *L. monocytogenes* – MTCC 657. The BOE-CuNPs with the lowest inhibitory activity were noticed against *P. aeruginosa* – MTCC 741. The qualitative antimicrobial activity, such as the zone of inhibition assay, confirmed that BOE-CuNPs have potential antibacterial activity. Rajesh *et al.*, (2018) provided evidence in favour of our study by demonstrating the potential antibacterial activity of *Syzygium aromaticum* bud extract-based CuNPs against different pathogens using the zone of inhibition experiment. Following the above-obtained results, the study further continued to estimate the quantitative antibacterial activity of BOE-CuNPs by broth dilution assay.

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Table 2 Antibacterial Activity of *Brassica oleracea* var. *gemmifera* Extract-Mediated Synthesized Copper Nanoparticles (BOE-CuNPs) Determined by Zone of Inhibition Assay.

S. No	Bacteria	Zone of inhibition (mm)	
		100 µg/well (BOE-CuNPs)	200 µg/well (BOE-CuNPs)
1	*Listeria monocytogenes* – MTCC 657	11.72 ± 1.28	19.20 ± 1.90
2	*Escherichia coli* – MTCC 41	13.39 ± 1.06	21.55 ± 2.14
3	*Pseudomonas aeruginosa* – MTCC 741	8.08 ± 0.79	15.02 ± 1.46
4	*Staphylococcus aureus* – ATCC 13565	10.41 ± 0.68	18.33 ± 1.80
5	*Enterococcus faecalis* – MTCC 439	9.37 ± 1.04	17.29 ± 1.34
6	*Klebsiella pneumoniae – ATCC 13883*	8.29 ± 0.72	16.74 ± 1.51
7	*Staphylococcus aureus – ATCC 14458*	10.06 ± 0.93	18.04 ± 1.29

Several researchers have claimed that tests have been conducted on bioinspired metal-based nanoparticles (such as copper, gold, silver, zinc, etc.) against fungi and bacteria. Researchers proposed that metal nanoparticles exhibit potential antimicrobial activity through variety of the following ways: (a) by building up metal ions in microbial membranes; (b) by producing excessive amounts of reactive oxygen species inside of microbes; (c) by rupturing microbial plasma membranes and impairing essential enzymes in the respiratory chain; (d) by electrostatically attracting metal nanoparticles to microbial cells and interfering with their metabolic processes; and (e) by inhibiting microbial proteins and enzymes and damaging the biomolecules. Despite the connections between these pathways, nothing is now known about the possible mechanisms underlying the majority of these biogenic nanoparticles (Yoon *et al.*, 2007; Rajesh *et al.*, 2018; Nisar *et al.*, 2019; Asghar & Asghar, 2020). In our study, as-synthesized BOE-CuNPs have presented potential antibacterial activity, and it could be useful in the biomedical industry as an antibacterial agent.

IV. CONCLUSION

The study concluded that *B. oleracea* var. *gemmifera* extract was successfully involved in the green synthesis of BOE-CuNPs and has excellent nanotechnological features. The as-synthesized BOE-CuNPs have free radical scavenging potential and could be useful in treating oxidative-stress-mediated conditions. Also, as-synthesized BOE-CuNPs have potential antibacterial activity and could be useful as an antibacterial agent in the biomedical field. However, to utilize BOE-CuNPs, an in-detailed functional and toxicological profile of BOE-CuNPs needs to be performed.

Conflict of Interest:- The authors declare that there is no conflict of interest

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