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ANTIBACTERIAL PROPERTIES OF COPPER NANOPARTICLES

In recent years, bacterial antibiotic resistance has become a serious problem, limiting the treatment options available to patients (Crisan, 2021). This has led to the intensive development of new types of antimicrobial agents, including those based on metal nanoparticles. Unlike antibiotics (such as chloramphenicol, streptomycin, ampicillin, and ofloxacin), CuNPs have several unique characteristics, including small size, large surface area, biocompatibility, and high biological and chemical reactivity, which contribute to their effectiveness in killing bacterial cells. Additionally, copper nanoparticles are cost-effective and environmentally friendly because they are produced using a biological technique (Longano, 2012). It has been established that copper nanoparticles exhibit powerful antimicrobial properties against gram-positive (*Bacillus subtilis, Bacillus cereus, Staphylococcus aureus*) and gram-negative (*Escherichia coli, Klebsiella sp., Pseudomonas aeruginosa, Salmonella typhi, Enterobacter sp.*) bacteria (Raju, 2022).

Copper nanoparticles can be assessed for their antibacterial properties using the standard disc diffusion method in agar. In studies, reference strains for gram-negative and gram-positive bacteria commonly include *Escherichia coli* and *Staphylococcus aureus*. Based on the literature reviewed, CuNPs showed an antibacterial zone of inhibition ranging from 10 ± 0.17 mm to 23 ± 0.52 mm. Antibiotic discs such as chloramphenicol, streptomycin, tetracycline, and the like were used for positive control. However, compared with some antibacterial drugs, the activity of the copper nanoparticles shows a clear inhibition zone (Raju, 2022).

The antimicrobial effect of nanoparticles on bacteria is due to the effect caused at the level of the cell wall. Gram-positive bacteria are more resistant to the mechanism of action of CuNPs since they have only a thick layer of peptidoglycan, in contrast to gram-negative bacteria, which, in addition to a thin layer of peptidoglycan, are surrounded by lipopolysaccharides with a negative charge related to the positive ions released by copper nanoparticles. Furthermore, it is important to note that the toxic effect of copper nanoparticles can vary depending on the concentration and size of the particles. In general, different sizes and concentrations of copper nanoparticles have antibacterial effects, but the minimum size and higher concentration of CuNPs demonstrate a wider zone of inhibition (Crisan, 2021).

Consequently, nanoparticles are increasingly being used as an alternative to antibiotics. Nanotechnology can be effective in the treatment and prevention of bacterial and fungal infections, which makes it possible to use them in antibacterial coatings for implanted devices, medical materials to prevent infection and promote wound healing, and antibacterial vaccines (Longano, 2012).

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THE VALUE OF TRICHODERMA IN BIOTECHNOLOGY

Trichoderma are soil green-spored ascomycetes, distributed worldwide and numbering about 370 species, 20 of which are actively used in agronomic biotechnology as bio-fertilizers and bio-fungicides. This is possible due to the physiological properties of *Trichoderma* spp. - the fungus has high adaptability, rapid growth of mycelium, symbiotic interactions with plants and several antagonistic mechanisms against pathogenic fungi and bacteria (Tyśkiewicz, 2022).

Trichoderma exhibits antagonistic activity against more than 18 species of pathogenic fungi, including *Pythium*, *Phytophthora*, *Rhizoctonia* and *Peronospora*, which are causative agents of root rot, late blight, potato scab and downy mildew. The main mechanism of suppression of pathogenic micromycetes is hyperparasitism (Korkom, 2023). *Trichoderma* is able to grow around the hyphae of the host, attach to