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Antimicrobial Activity of Selenium-Containing Nanoparticles



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Abstract

SeNPs, or selenium-containing nanoparticles have antimicrobial properties against bacteria and fungi. Reactive oxygen species production, cell membrane disruption, and or interference with intracellular processes are some of their mechanism that explains these properties. They are efficient against bacteria resistant to antibiotics because functionalization increases their selectivity and lowers host toxicity. Furthermore, SeNPs have intriguing uses in antimicrobial therapy due to their ability to work both in combination with traditional antibiotics and on their own. This mini-review highlights the potential of SeNPs as novel substitutes for antimicrobial agents, while emphasizing the need for further research on their safety, scalability and applications.

Keywords: Selenium nanoparticles; Antimicrobial activity; Antibacterial properties; Antifungal properties; Antibiotic resistance

Abbreviations: SeNPs: Selenium Nanoparticles; SeNWs: Selenium Nanowires; MSSA: Methicillin Sensitive *S. aureus*; VRE: Vancomycin Resistant Enterococci; RGO: Reduced Graphene Oxide

Introduction

Selenium (Se) is a nonmetal element, with the chemical symbol Se and belongs to group VI a of the periodic table with properties that are intermediate between tellurium and sulfur [1,2]. This element is a necessary micronutrient that was found by Jons Jacob Berzelius. Amorphous and crystalline structures are among its three allotropic types. Although selenium has commercial applications such as solar cells and xerography, nanosized selenium particles (SeNPs) have drawn interest due to their low cytotoxicity and antibacterial, antitumor, antioxidant and antibiofilm qualities [3]. The study of selenium nanoparticles and their antimicrobial properties is a relatively new field of research, and interest in this topic has been growing rapidly in recent years driven by the increasing challenge of antimicrobial resistance [4].

Discussion

Antibacterial properties

Before the 1920s, bacterial infections were the leading cause of death globally, but the introduction of penicillin and subsequent antibiotics like streptomycin and vancomycin marked a significant breakthrough in combating these infections. Despite these

advancements, lower respiratory infections remain a major global cause of death due to the rise of antimicrobial resistance, which enables bacteria to counteract the efficacy of antibiotics [5].

Conversely, nanomaterials offer a promising alternative to conventional antibiotics by introducing novel drugs that could address certain recognized limitations. Nanomaterials can function either as carriers for other therapeutic agents or as therapeutic agents in their own right [5]. Selenium nanoparticles have diverse biomedical applications including immunomodulatory, neuroprotective, antibacterial and antifungal properties [5-7]. For example, Han et al. [8] evaluated the antibacterial effect of selenium nanoparticles (SeNPs) and selenium nanowires (SeNWs) combined with linezolid against multidrug-resistant bacteria. They reported MIC values for SeNPs with the following strains -methicillin-sensitive *S. aureus* (MSSA), methicillin-resistant *S. aureus* (MRSA), vancomycin-resistant enterococci (VRE) at concentration values of 20, 80, 320 and >320 µg/mL. Salah et al. [9] reported the antibacterial effect of PVP selenium nanoparticles on *S. aureus*, *B. cereus*, *K. pneumoniae*, *E. coli* and *P. aeruginosa*. The nanoparticles showed MIC values around 1.252 µg/mL for the representatives of Gram-positive bacteria -*S. aureus* and *B. cereus*.

For the Gram-negative bacteria the MIC values stands at 0.626 µg/mL for *E. coli* and 0.313 µg/mL for *P. aeruginosa* and *K. pneumoniae*. Niranjana et al. [10], evaluated the antibacterial properties of Sulfur-Selenium nanoparticles loaded on reduced graphene oxide (rGO) against Gram-positive bacteria. Their study reported that rGO-S/Se at concentration 200 µg/mL inhibited bacterial growth of *E. faecalis* with 87%. For *S. aureus* the inhibitory effect stands at concentration values of 150 µg/mL.

In the study of Elmaaty et al. [3] was reported the properties of printed polyester fabrics with SeNPs. The following strains were tested with different concentrations (25mM and 50mM) -*E. coli*, *S. typhi*, *P. aeruginosa* and *B. cereus*. This study evaluated that the synthesized NPs showed good antibacterial effect compared to antibiotics like tetracycline and ciprofloxacin. The fabric printed with the lower concentration of SeNPs (25mM) has stronger antibacterial effect on all used strains compared to the fabric printed with the higher concentration (50mM). The lack of concentration effect may be due to agglomeration of nanoparticles on the printed fabric. El-Sayyad et al. [11] conducted a study evaluating the effect of gentamicin-assisted myogenic SeNPs synthesized under gamma radiation and their antimicrobial effect on multidrug-resistant bacteria and yeast leading to serious urinary infections. The results from the disc agar diffusion method showed that the NPs were efficient upon *S. aureus*, *C. albicans* and *P. aeruginosa*.

Antifungal properties

Fungal infections are a significant yet often underestimated health burden, affecting approximately 150 million people annually and causing 1.5 million deaths. Key pathogens include *Aspergillus* species, leading to sinopulmonary and disseminated diseases in cancer and transplant patients; *Cryptococcus neoformans* causing meningoencephalitis in immunocompromised individuals; and *Candida* species, responsible for bloodstream and deep-seated infections in hospitalized patients [12]. Drug resistance in *Candida* species has significantly risen over the past decades. Due to the challenges posed by antifungal resistance, as well as the toxicity and interactions associated with current antimicrobial drugs, the development of new antifungal agents is crucial [13]. For example, Bafghi et al. [14] reported the biosynthesis of SeNPs by *A. flavus* and *C. albicans* and their antifungal properties. The NPs that were synthesized from *A. flavus* were used on *Aspergillus* strains, respectively the NPs synthesized by *C. albicans* were used on *Candida* species. The results showed the inhibition of *C. albicans* at concentration lower than 1 µg/mL and for *C. krusei*, *C. glabrata* and *C. tropicalis* the concentrations that prevented growth were 0.5 µg/mL and 0.25 µg/mL.

In another study, Loftali et al. [7] compared the antifungal properties of different metal NPs against amphotericin B-resistant *C. glabrata* strains. The isolates were tested with Ag, Se and Au NPs. Scanning electron microscopy showed that SeNPs have impact of

the morphology the cell membrane was disrupted at concentration 2X MIC dose. Bafghi et al. [13], reported another study on the green synthesis of SeNPs and their effect on resistance genes expression in *C. albicans* and *C. glabrata*. This research showed that SeNPs can effectively reduce the expression of key antifungal resistance genes- ERG3, ERG11, and FKS1- which are critical components of the ergosterol biosynthesis pathway in both of the investigated pathogens [14].

Conclusion

Selenium-containing nanoparticles exhibit promising antimicrobial properties, showing efficacy against a range of pathogens, including those resistant to antibiotics and antifungal agents. This mini-review highlights those certain challenges, such as determining optimal concentrations and fully understanding the mechanism of action of SeNPs, remain unsolved, which will likely drive future scientific research.

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