ANTIBACTERIAL ACTIVITY OF GOLD NANOCOMPOSITES

Seniuk I.V., Filimonova N.I., El Mehdi Tolbi, Benzid Yassine
National University of Pharmacy, Kharkiv, Ukraine
citochrom@gmail.com

Introduction. Antibacterial agents are crucial in several areas of science, such as medicine, industrial materials, food packaging, and water treatment. Antimicrobial activity can be defined as a collective term for all active principles that inhibit bacterial growth, prevent the formation of microbial colonies, and may destroy microorganisms. Organic compounds as conventional disinfectants are cytotoxic and also cause health problems. Therefore, a focus on developing inorganic disinfectants has gained extensive attention: for instance, nanoparticle (NP) enhanced antibacterial activity without creating toxicity to surrounding tissues. Over the past decade, different synthetic methods, such as the microemulsion technique, sol-gel method, and aerosol technique, have been applied to synthesizing nanoparticles. Their time-consuming nature, the high cost of production, and contamination with toxic chemicals have restricted the practical use of nanoparticles in biomedical applications. To overcome these limitations, low-cost green synthetic techniques were developed in which substances with low toxicity are utilized.

The aim. To study the antibacterial activity of gold based on nanoparticles.

Materials and methods. A literature review of the antibacterial activity of metal-based nanocomposites was conducted; a separate review of the antibacterial activity of AuNP salong with the antibacterial mechanism was conducted; the introduction of advanced gold-based nanocomposites for antibacterial activity; and a review of some bacteria most affected by AuNP.

Results and their discussion. Metal-based nanoparticles act as non-specific antibacterial agents since they do not bind to a specific receptor in the bacterial cell. Moreover, metal-based nanoparticles prevent the development of resistance by bacteria and expand the range of antibacterial activity. The results show electrostatic interactions between the cell surface and nanoparticles as the primary step towards nanotoxicity, tracked by an increase in membrane permeability, morphological cell changes, and their accumulation in the cytoplasm. It is well understood that silver and copper nanoparticles have antibacterial activity against *Bacillus subtilis* and *Staphylococcus aureus*. Rupture of the plasma membrane, cell wall damage, and disturbing the biochemical process have been reported as the main mechanisms. Reduced enzymatic activity, the release of Cu^{2+}, and changes in NADPH production were described as the antibacterial activity of Cu-doped TiO_2 NPs toward *Mycobacterium smegmatis*. Adsorption and penetration of AgNPs and toxicity with electrostatic interaction were revealed as the underlying mechanisms against *Klebsiella pneumoniae*. For the eradication of *Pseudomonas aeruginosa*, ZnO NPs can be used appropriately. Applied nanoparticles could disrupt the membrane, generate reactive oxygen species (ROS), and disturb cell wall permeability. Electrostatic interaction altering bacterial attachment, damage to the bacterial cell wall, and improved permeability were demonstrated as the mode of action for Al_2O_3 nanocomposites as antibacterial agents. Growth inhibition, particularly in an aqueous medium, physical and mechanical stresses on cellular structural integrity, and significant damage to cellular functions are the main antibacterial activity points of NiO NPs against *Escherichia coli (E. coli).* Frameshift mutation and ROS generation are reported as the bacterial killing mechanism for TiO_2 NPs against *Salmonella typhimurium*. Disturbing the permeability and cell division, and interaction with sulfur- and phosphorus-containing compounds and the cell membrane are the mechanisms of Ag NPs against *E. coli*.

Gold nanoparticles (AuNPs) are considered the main candidate in numerous fields, such as nanobiotechnology, tissue engineering, and drug delivery. Chemical sensing and drug delivery technology are recognized as potential users of AuNPs due to the high affinity of AuNPs with organic species, and their high electrical conductivity.

The antibacterial activity of metal-based nanoparticles is promising in several fields, especially in medical areas. The size of the nanoparticles plays a fundamental role in their functional training, such as chemical and biological activity. Discovering the molecular mechanism of the antibacterial action of nanoparticles is an attractive aspect of nanobiotechnology. Inhibiting DNA replication, damaging the cell membrane, and inactivating proteins are the main antibacterial activity mechanisms of AgNPs. Affecting the purine metabolite pathway is another antibacterial mechanism of silver nanoparticles. Reactive oxygen species (ROS) aid as cell signaling molecules for regular biologic processes. However, the generation of ROS may damage many cellular and molecular processes. A high surface-area-to-volume ratio is one of the most essential properties of noble nanoparticles. Nanoparticles enable a greater presence of atoms on the surface and suitable contact with the environment. Therefore, AgNPs make penetration through the cell membrane easier, cooperating with intracellular materials and allowing cell destruction. Accordingly, TiO_2 and ZnO NPs could kill bacteria via ROS-production under UV irradiation. Carbon-based nanoparticles may cause mechanical damage or apply oxidants for antibacterial activity. Some crucial aspects that make the AuNPs remarkable in their antibacterial activities include facile synthesis methods, high functionalizability, strong interaction with the bacterial membrane, and their inherent biocidal activity.

Conclusions. AuNPs are among the main nanomaterials utilized in nanobiotechnology. According to the above examples, gold nanocomposites have antibacterial properties. The most important factors in the development of antibacterial gold-based nanocomposites can be considered to be: the facile fabrication with low cost is one of the most fundamental factors in the development of nanobiotechnology; therefore, the use of low-cost materials, such as carbon-based compounds, along with AuNPs should be considered. The cytotoxicity of AuNPs is one of the most pressing challenges in its application in an in vivo environment; therefore, researchers should focus on reducing their toxicity. Various studies have shown that gold nanoparticles in combination with different materials exhibited different antibacterial activities. For this reason, the choice of nanocomposite components is essential.

To date, there are several mechanisms to describe the antimicrobial performance of AuNPs. As a result, theoretical and experimental investigations of the metabolisms of AuNPs in bacteria are still unclear and require comprehensive study for a correct understanding of their antimicrobial activity. Finally, serious work needs to be completed to expand the antimicrobial activity of AuNPs towards clinical application. In other words, we believe that gold nanocomposites can be used as antimicrobial agents in the clinic in the near future.