Chelonian Conservation And Biology

Vol. 18 No. 2 (2023) | https://www.acgpublishing.com/ | ISSN - 1071-8443

DOI: doi.org/10.18011/2023.12(2).2532.2542

SYNTHESIS AND ANTIMICROBIAL ACTIVITY OF SILVER NANOPARTICLES

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Abstract

Nanoparticles, which are the tiniest components of nanotechnology, are currently exerting a significant influence across multiple domains of our daily existence. The frequent use of antibiotic drugs is responsible for the development of multidrug resistance (MDR) in pathogenic microorganisms, which is a significant obstacle to effectively diagnosing and treating infectious diseases. Nanoparticle-based therapy is a promising method to enhance the effectiveness of systemic therapeutic intervention while minimising its toxicity. Silver nanoparticles (AgNPs) have gained significant attention in the field of biomedicine due to its diverse applications, such as

antibacterial therapy, wound dressings, diagnostic and treatment, and contraceptive devices. Therefore, AgNPs are a highly promising therapeutic agent that has the ability to successfully combat numerous microbial diseases, including antibiotic-resistant bacteria. Hence, the creation of a therapy plan centred around AgNPs to amplify the antibacterial impact is an innovative and encouraging method. The utilisation of plant extracts for the production of nanoparticles, known as green synthesis, offers a very effective alternative to the traditional procedures using chemical and physical processes. These conventional methods often result in the generation of environmentally harmful by-products.
Keywords: Silver Nanoparticle, Green synthesis, antibacterial activity.

Brief Introduction of Silver Nanoparticle

Nanoparticles (NPs) are the most basic structures, characterised by sizes ranging from 1 to 100 nm. In general, any group of atoms that are linked together and have a structural radius smaller than 100 nm can be classified as a nanoparticle. These nanoparticles serve as a connection between larger materials and atomic or molecular structures. As materials become smaller and approach nanoscale dimensions, they exhibit unique behaviour and properties that differ from their larger counterparts. These properties are influenced by the size and shape of the nanomaterial. The small size of nanomaterials results in a higher surface area to volume ratio, meaning there are more atoms on the surface compared to the interior. Recent progress in understanding the properties of nanomaterials has allowed researchers to develop new materials with novel behaviour for various applications [1-5].

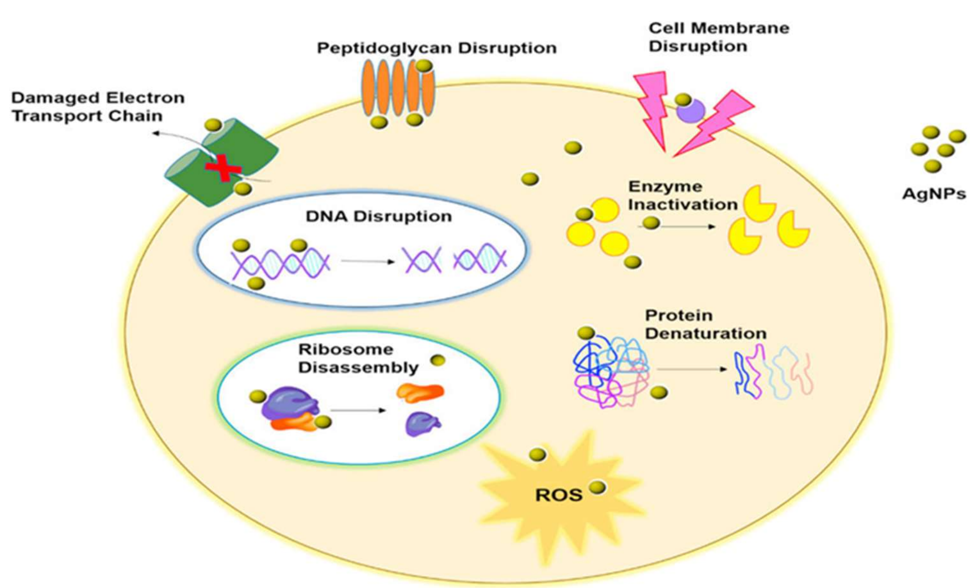

Figure 1: The mechanism of antibacterial activity of silver nanoparticles.

Some nanoparticles possess positive charges, while others possess negative charges, and some are neutral. Nanoparticles can be categorised as either magnetic or nonmagnetic, and they can also be categorised as organic (mostly composed of carbon) or inorganic (such as silver nanoparticles or gold nanoparticles). Silver nanoparticles have become a significant category of nanomaterials with diverse uses in industries and medicine.

Silver nanoparticles (Ag NP) are currently the most commercially utilised among all nanoparticles found in consumer items. Ag NP uses have been used in several consumer products, including disinfecting medical devices, home appliances, and water purification. Moreover, the distinctive optical scattering properties of Ag NPs make them suitable for applications in bio-sensing and imaging. This has been demonstrated by studies conducted by Dubas and Pimpan in 2008, as well as Schrand et al. in the same year. What is more significant is the

The potential for utilising Ag NP in the treatment of disorders that necessitate the maintenance of medication concentration in the bloodstream or the targeting of particular cells or organs. Ag NPs, as demonstrated by Elechiguerra et al. (2005), have the capability to interact with the HIV-1 virus and hinder its capacity to attach to host cells in a laboratory setting [6-10].

Synthesis of Silver Nanoparticles

Every day, new ways are being developed to make the synthesis of nanoparticles easier and more successful. There are three main methods utilised for synthesising nanoparticles: physical, chemical, and biological methods. The physical methods used for nanoparticle synthesis include pulsed laser desorption, plasma arcing, spray pyrolysis, ball milling, thermal evaporation, ultra-thin films, sputter deposition, lithographic techniques, layer by layer growth, molecular beam epitaxy, and diffusion flame synthesis. The chemical methods commonly employed for synthesising NPs include electrodeposition, sol-gel process, chemical vapour deposition, chemical solution deposition, soft chemical method, Langmuir Blodgett method, hydrolysis and catalytic route, wet chemical method, and co-precipitation method. The use of high radiation and highly concentrated reductants and stabilisers in chemical and physical processes poses significant risks to the environment and human health. Therefore, the biological synthesis of nanoparticles is a method that involves a single step bio-reduction process, requiring minimal energy to produce environmentally benign NPs. In addition to this, biological approaches utilise environmentally beneficial resources such as plant extracts, bacteria, fungi, microalgae such as diatoms, cyanobacteria, seaweed (macroalgae), and enzymes.

Synthesis of silver nanoparticles using environmentally friendly methods Bacterial-mediated synthesis of silver nanoparticles:

The initial proof of bacteria producing silver nanoparticles was demonstrated by utilising the Pseudomonas stutzeri AG259 strain, which was obtained from a silver mine. Certain microbes possess the ability to withstand high levels of metal ions and are capable of thriving in such environments. This resilience is attributed to their resistance to metal ions.

The silver nanoparticles were formed as a result of this process. Mesophytes were found to contain three forms of benzoquinones: cyperoquinone, dietchequinone, and remirin. It was claimed that these phytochemicals play a direct role in reducing ions and forming silver nanoparticles. The biological creation of silver nanoparticles using plant extract [11-20].

Synthesis of Silver Nanoparticles by Fungi

Compared to bacteria, fungus have the ability to generate larger quantities of nanoparticles due to their capacity to secrete greater amounts of proteins. This directly results in a higher level of nanoparticle productivity. The process of silver nanoparticle synthesis by fungi is believed to proceed via the following stages: The process involves the capture of Ag+ ions on the surface of the fungal cells, followed by the enzymatic reduction of the silver ions within the fungal system. The extracellular enzymes, such as naphthoquinones and anthraquinones, are believed to aid in the reduction process. For instance, in the case of F. oxysporum, it is hypothesised that the formation of nanoparticles is facilitated by the NADPH-dependent nitrate reductase and a shuttle quinine extracellular process. While the precise mechanism of silver nanoparticle generation by fungus remains incompletely understood, it is assumed that the aforementioned phenomena is responsible for this process. One significant limitation of employing microorganisms for synthesising silver nanoparticles is its relatively modest speed compared to plant extracts. Therefore, utilising plant extracts for the synthesis of silver nanoparticles is a viable alternative [31-30].

Plant-mediated synthesis of silver nanoparticles

One significant benefit of utilising plant extracts for the synthesis of silver nanoparticles is their ready availability, safety, and non-toxic nature in most instances. Plant extracts possess a wide range of metabolites that can facilitate the reduction of silver ions, and they are faster in the synthesis process compared to microorganisms (Jha et al., 2009). The primary mechanism under consideration for the process is plant-assisted reduction facilitated by phytochemicals. The key phytochemicals involved include terpenoids, flavones, ketones, aldehydes, amides, and carboxylic acids. Flavones, organic acids, and quinones are hydrophilic phytochemicals that have a role in the prompt reduction of ions. Research has shown that xerophytes possess emodin, an anthraquinone compound that undergoes tautomerization.

Importance of Green Synthesis

Green synthesis is a sustainable method that avoids the use of harmful chemicals. This technology is revolutionary as it unlocks the potential of plants in synthesising stable nanoparticles, extends the lifespan of the synthesised nanoparticles, and overcomes the limits of chemical and physical procedures. The use of plants for the synthesis of nanoparticles (NPs) is a faster and more reliable technique compared to conventional methods. This technique scales up the production process of commercially applicable NPs while minimising toxicity. Plants are able to actively uptake and reduce metal ions, making them suitable for NPs synthesis and bioremediation. As a result, complex metal NPs can be formed. Green synthesis offers several advantages compared to physical and chemical methods. It is cost-effective, environmentally benign, and easily scalable for large-scale synthesis. Additionally, this method eliminates the need for high pressure, temperature, energy, and harmful chemicals. The process of green synthesis of nanoparticles involves the utilisation of environmentally friendly, non-toxic, and safe reagents. Phytomining, on the other hand, refers to the extraction of metals from plant biomass using hyperaccumulating plants, with the aim of generating economic profit.

The utilisation of nanomaterials in several industries has gained significant attention recently due to their unique physicochemical features. The metallic nanoparticles, including gold, silver, platinum, zinc, copper, titanium oxide, magnetite, and nickel, were synthesised from natural resources and have been solely researched. Various components of plants, including the stem, root, fruit, seed, callus, peel, leaves, and flower, are utilised in biological methods to synthesise metallic nanoparticles of varied shapes and sizes. While bacterial, fungal, and plant extracts can all be used for nanosilver synthesis, plant extracts are the optimal choice due to their easy availability, non-toxic nature, wide range of options, and the advantage of faster synthesis. This conclusion was drawn by Kulkarni and Muddapur in 2014. The biosynthesis reaction can be modified by varying the metal concentration and the quantity of plant extract in the reaction medium. This alteration has the potential to change the morphology and dimensions of the nanoparticles [31-35].

Applications of Silver Nanoparticles in Biology

AgNPs have been widely utilised in several fields such as house-hold items, the health care business, food storage, environmental applications, and biological applications, owing to their distinct characteristics. Multiple reviews and book chapters have been devoted to exploring the diverse applications of AgNPs in various fields. In this study, we aim to highlight the diverse uses of AgNPs in several biological and biomedical fields, including their effectiveness against bacteria, fungi, viruses, inflammation, cancer, and angiogenesis. In this study, we focused on previously-published influential studies and concluded with the most recent updates from Zhang et al. (2016). Figure 2 presents a schematic diagram illustrating the diverse applications of AgNPs. In 2006 Gogoi investigated the antibacterial effect of silver nanoparticles against E. coli expressing green fluorescent protein (GFP) bacteria. The green fluorescent proteins (GFPs) were adapted to these studies. The result showed that silver nanoparticles get attached to sulfur containing proteins of bacteria cell causing the death of the bacteria. The fluorescent measurements of the cell-free supernatant reflected the effect of silver on recombination of bacteria. Lok et al. (2006) elucidated that AgNPs exhibited destabilization of the outer membrane and rupture of the plasma membrane, thereby causing depletion of intracellular ATP.

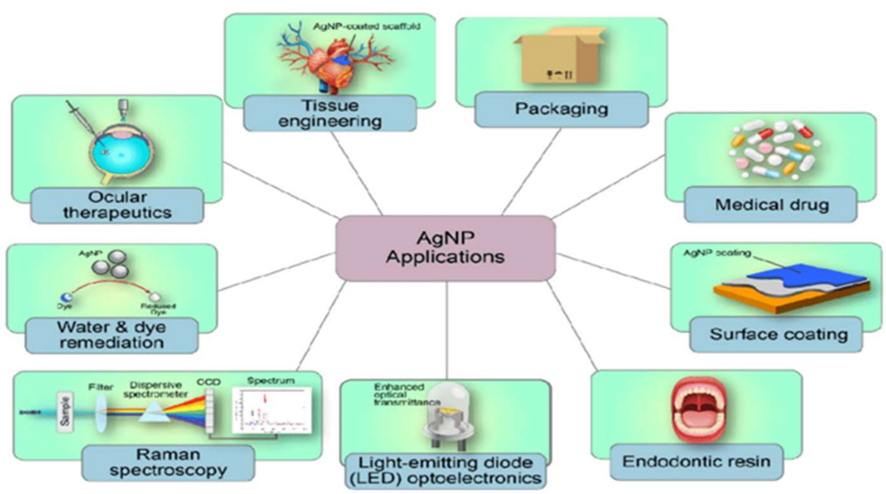

Fig. 2: The various applications of AgNPs.

Silver nanoparticles' antibacterial activity

Silver nanoparticles exhibit both enhanced and unique properties at the nanometer scale. However, the antimicrobial effects of these particles have received the most attention in scientific literature. Studies have demonstrated their enhanced antibacterial effects against bacteria and fungi, as well as their antiviral effects against viruses such as HIV-1.

Ancient civilizations were aware of the influence of silver and its compounds. They have been used for a long time to purify water and disinfect medical devices. In the field of medicine, silver compounds are commonly employed to treat wounds, burns, and various infectious diseases.

Recently, Silver Nano particles have gained attention for their potential in producing novel antimicrobials, which offer a new approach to combat a variety of bacterial diseases. Previous beliefs suggested that bacteria are less likely to develop resistance to silver compared to conventional and narrow-target antibiotics. This is because silver attacks a wide range of targets within the organisms, requiring the bacteria to simultaneously develop multiple mutations in order to protect themselves [36-49].

In their study, Sondi and Salopek-Sondi (2004) examined the antibacterial properties of silver nanoparticles. These nanoparticles were synthesised by reducing silver nitrate using ascorbic acid. The researchers used E. coli as a model to represent Gram-negative bacteria. Morones et al. (2005) observed that silver nanoparticles exhibited lethal effects on E. coli bacteria. Additionally, it was demonstrated that silver possesses antimicrobial properties. Shahverdi et al. (2007) conducted a study on the strong combined effect of silver nanoparticles and erythromycin medicines against Staphylococcus aureus. Subsequently, Kong and Jang (2008) conducted a study on the antibacterial characteristics of silver nanoparticles that were synthesised biologically and integrated into textile fabric, resulting in significant suppression. Birla et al. (2009) stated that silver nanoparticles have significant potential in biology, such as antibacterial agents and for DNA sequencing. The antibacterial efficacy of silver nanoparticles against Staphylococcus aureus, Pseudomonas aeruginosa, and Escherichia coli has been examined [50-60].

Lara et al. (2010) suggested an alternative method by which silver can kill bacteria. This method involves blocking the manufacture of the cell wall, as well as the production of proteins and nucleic acids, which are controlled by the 30s ribosomal subunit. In 2012, Dipankar and Murugan conducted a study on the production and analysis of silver nanoparticles utilising Iresine herbstii. They also assessed the antibacterial properties of these nanoparticles. Vijayakumar et al. (2013) found that Asteraceae-synthesized silver nanoparticles exhibit high susceptibility to several microorganisms. The antibacterial capability of silver nanoparticles synthesised by Priyadarshini et al. (2013) utilising the Bacillus flexus S-27 bacterial strain was found to be highly effective.

The study conducted by Fouda et al. (2013) examined the antibacterial properties of nanofibers made from carboxymethyl chitosan and polyethylene oxide, which contained embedded silver nanoparticles. The researchers Sulaiman et al. (2013) synthesised silver nanoparticles using extracts from Eucalyptus leaves. They then investigated the antibacterial efficacy of these nanoparticles against various pathogenic bacteria and yeast, as well as their toxicity against human acute promyelocytic leukaemia (HL-60) cell lines [61-69].

Conclusion

The use of nanoparticle-based therapy has the potential to both lessen the toxicity of systemic therapeutic intervention and increase its efficacy. Because of their many uses in the biomedical area, such as antibacterial therapy, wound dressings, diagnostics and therapies, and contraceptive devices, silver nanoparticles, or AgNPs, have attracted a lot of attention. AgNPs are an extremely promising therapeutic agent that can successfully treat a wide range of microbiological diseases, including bacteria that are resistant to antibiotics. As a result, creating a treatment plan that emphasizes AgNPs to strengthen the antibacterial impact is a fresh and effective idea. Utilizing plant extracts to create nanoparticles is known as "green synthesis," and it offers a very effective substitute for traditional techniques that depend on chemical and physical processes. These conventional methods often result in the development of by-products that are harmful to the environment.

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