American Journal of Botany and Bioengineering
https://biojournals.us/index.php/AJBP
ISSN: 2997-9331

Study the Synthesis and Produce Silver Nanoparticles and their Antibacterial Role (Subject Review)

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Received: 2024 19, Nov
Accepted: 2024 28, Dec
Published: 2025 22, Jan

Annotation: Nanotechnology is a branch of technology that uses materials having at least one dimension between 1 nm and 100 nm to generate new materials and products. Nanomaterials are very different from macroscopic materials and have only recently caught the interest of researchers because of their unique, superior, and significant properties. Two significant distinctions are their high surface-to-volume ratio and the higher concentration of atoms at grain boundaries. Materials such as metal, metal oxide, carbon nanomaterials have been widely exploited as new antibacterial agents because of their small sizes, unique chemical and physical characteristics, and high specific surfaces. Silver nanoparticles have been widely used in sectors like biomedicine, pharmacy, and cosmetics because of their special antibacterial properties. Because of their broad-spectrum antimicrobial qualities and potent antibacterial efficacy against a variety of bacteria, viruses, and fungi, Silver (Ag) nanoparticles are the most commonly employed antibacterial nano-agent among the different manufactured nanoparticles that are used in antibacterial therapies.

Keywords: nanotechnology, Silver (Ag) nanoparticles, antibacterial activity.

Introduction

Nanotechnology is a branch of technology that works with materials that have at least one dimension between 1 nm and 100 nm to create new materials and products. Nanomaterials are very different from macroscopic materials and have only recently caught the interest of researchers because of their unique, superior, and significant properties. Two significant distinctions are their high surface-to-volume ratio and the higher concentration of atoms at grain boundaries (Saleh 2019; Saleh and Hussein 2020; Saleh et al. 2021 & 2024). According to Annamalai et al. (2016), nanomaterials are essential for developing new technologies that can be used in a wide range of fields, such as physics, biology, biomedicine, pharmacology, cosmetics, and many other product industries.

It has recently been demonstrated that nanotechnology can effectively treat infections caused by bacteria. In 1870, the English physician John Scott Burdon Sanderson discovered the link between mold development and pathogens. Alexander Fleming is credited with the accidental discovery of penicillin in 1928. Penicillin had a major influence on antibacterial treatment since, at the time of its invention, the majority of infectious diseases were lethal. Penicillin affected Gram-positive bacteria as soon as it was used. The overuse of antibiotics in contemporary times has led to the development of immunity in many bacterial strains. Many drugs with potent antiviral, antifungal, and antibacterial properties were developed after the first reports. Antibiotic overuse has two primary effects: increased microbial resistance and the development of multiresistant germs, which endangered the lives of some patients (Annamalai et al. 2016, Esmaeillou et al. 2017; Saleh 2018).

As a result, new methodologies were required to generate novel compounds with antibacterial capabilities while keeping low toxicity levels suited for medical uses. The 1980s saw the development of the most modern antibacterial drugs. No significant discovery has been made since. Vancomycin, one of the original antibiotics, has been used for over 50 years to treat infections brought on by Staphylococcus aureus bacteria that are resistant to methicillin. New strains of bacteria that are resistant to vancomycin begin to appear as the bacteria change throughout time. Therefore, the development of new drugs is always necessary. One concept for enhancing medications is effect augmentation with nanoparticles, which allows the binding of different substances (Esmaeillou et al. 2017).

Materials such as metal nanoparticles (da Silva et al. 2020), metal oxide nanoparticles (Keshavarz et al. 2020), carbon nanomaterials (Alavi et al. 2020), Because of their compact size, distinct chemical and physical properties, and high specific surfaces, these composites have been widely exploited as new antibacterial agents. Silver nanoparticles have been widely used in industries such as biomedicine, and skincare because of their particular antibacterial property (Yuwen et al. 2018).

AgNPs have been found to have better antibacterial properties, lower toxicity, and more biocompatibility than other metallic particles. The observations and data on AgNPs' broad-spectrum antibacterial activity provide a foundation for future antibacterial-specific applications. More recently, it has been established that Ag nanoparticles have a stronger potential to prevent bacterial growth and are less likely to have harmful side effects than antibiotics (Annamalai et al. 2016, Yuwen et al. 2018).

Metal Nanoparticle Synthesis

Metal nanoparticles can be produced using the green method, which uses various chemicals and reagents, prokaryotic bacterial cells, eukaryotic fungi, plant extract, leaves, flowers, and plants. Physical techniques, which have already been developed, will also be reviewed.

Green Methods

One-step synthesis is made possible by the use of biological organisms, mold, algae, and plants. The reduction method produces nanoparticles using proteins and enzymes present in microorganisms and plants. In addition to being often less costly than chemical procedures, the green production of metal nanoparticles has the advantage of employing more ecologically acceptable materials. One of the plants described above is the reducing agent utilized to transform the metallic silver precursor into metallic NPs. They also provide a sustainable supply of bioactive substances for the synthesis of metallic nanoparticles. The procedure can lessen the harmful effects and has a minimal influence on the environment (Rauwel et al. 2015).

In a recent study, Garcinia mangostana rind extract was used to create silver nanoparticles. The authors detached the rind, washed it of impurities, and allowed it to dry at room temperature for ten days. The dried rind was then mixed and sieved to yield consistently sized particles. 1.5 g of obtained particles were suspended in 50 milliliters of distilled water for fifteen minutes at 50-70 degrees Celsius. One of the problems of the green approach is managing the size and structure of the nanoparticles. Temperature is believed to have the greatest influence on material production (Nishanthi et al. 2019). The scientists discovered that lower temperatures did not produce nanoparticles. However, when the temperature was raised to 80 degrees Celsius, the authors saw the creation of metallic nanoparticles. Furthermore, at temperatures around 100 degrees Celsius, the reaction rate is relatively high, limiting particle production. The shape of nanoparticles is affected by temperature; at lower temperatures, tiny spherical particles are found, whereas at higher temperatures, platelet nanoparticles and nanorods are seen. Reaction time is another factor to consider when doing the synthesis (Chitra et al. 2014).

Chemical Methods

Chemical reduction, light-induced reducing, microwave-assisted manufacturing, UV-initiated photo reduce, electrochemical synthetic methodology, and irradiation approaches are some of the chemical methods used to create nanoparticles (Raza et al. 2016).

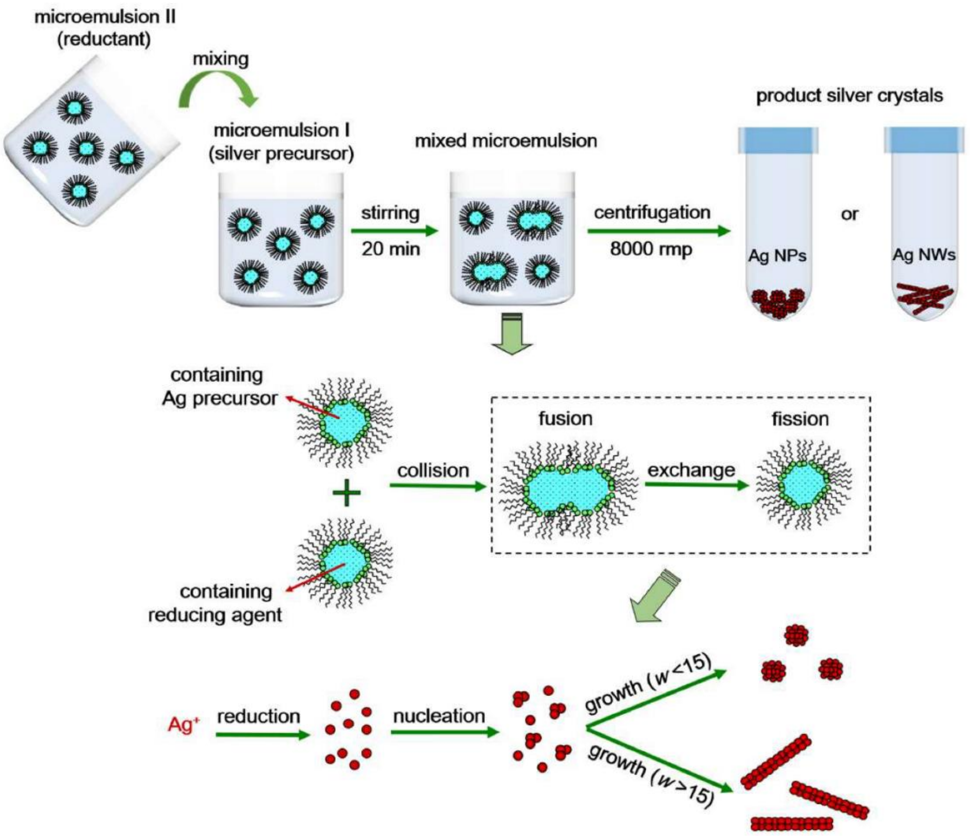

Figure 1. the reaction process using a reverse microemulsion technique.

The following steps are part of the multi-step synthesis process that the authors suggest: (1) water droplets dispersing in a continuous oil phase; (2) surfactant molecules stabilizing the water/oil interface; (3) mixing the two microemulsions; (4) water droplet collisions and reactant exchanged form; (5) nucleation reaction; (6) growth of AgNPs; and (7) surfactant molecules adhering to the nano surface (Feng et al. 2018).

Among the most commonly used procedures are those cited by Turkevich and Khan. The following steps are included in this method: After dissolving 9 mg of AgNO3 in 49 mL of ultra-pure water, the mixture is heated to 100 °C while being stirred. The mixture is permitted to reach room temperature after forty-five minutes. One milliliter of a 38.8 mM sodium citrate solution is then added, and large particles are eliminated by centrifuging the mixture for an hour at 500 rpm. The pure and stable AgNPs that are formed are then preserved at 4 °C. Using Turkevich's method, Tian et al. (2015) evaluated the generated nanoparticles' antibacterial activity against S. aureus. They found that AgNP concentrations greater than 1 mg/L could inhibit bacterial growth.

Physical Methods

For physical synthesis, evaporation-condensation and laser ablation are the two most important methods. The advantages of using a physical approach over a chemical one include the homogeneity of nanoparticle distribution and the absence of solvent contamination. Using the evaporation-condensation technique, very tiny nanoparticles can be created. According to Iravani et al. (2014) and Khan et al. (2018), the process is time- and energy-intensive because energy is needed to raise the working temperature. Factors influencing the laser ablation technique include the laser's wavelength, pulse duration, fluence, ablation period, and liquid media. The scientists created nanospheres in water using femtosecond laser pulses at 800 nm (Iravani et al. 2014).

Antibacterial role

Pharmaceutical companies have spent the last 30 years creating new antibiotics that are more efficient at stopping the construction of bacterial cell walls and the creation of proteins, and DNA replication. Despite these advancements, there is still a high death rate from bacterial infections because of the rise in antibiotic resistance. The resistance of microorganisms to conventional antibiotics is one of the most significant problems facing global healthcare (Sui et al. 2018).

The application of nanomaterials is growing and becoming more and more important in our day-to-day activities. Low-cost, non-toxic materials with a wide range of applications in the pharmaceutical, cosmetic, medical, and industrial sectors are sought for. One important use for these materials is the management of diseases and drug-resistant microbes (Shilba et al. 2015). Drug delivery for small molecules has been accomplished with success using semiconductor nanoparticles, silver, gold, and platinum. The antibacterial properties of nanoparticles made them very efficient against bacteria, and multivalent interactions resulting from their large surface area allowed for significant synergy (Kumar et al. 2017).

AgNPs are the most commonly used antibacterial nano the agent among a number of engineered nanoparticles that are utilized in antibacterial therapies due to their strong antibacterial efficacy and broad-spectrum antimicrobial properties against a variety of bacteria, viruses, and fungi (Tang and Chen 2019). In 1881, silver was used for the first time in recorded medical history to treat eye infections in newborns. It was later used as an internal antisepsis in 1901. These days, silver-containing drugs like silver nitrate and silver sulfadiazine are commonly used to treat cutaneous burns, wounds, and wart removal (Annamalai et al. 2016).

Although the primary biological target of Ag nanoparticles is yet unknown, it is known that they interact with the bacterial cell membrane (Bondarenko et al. 2013). Silver nanoparticles with antibacterial properties can effectively combat 650 distinct illnesses. Ag nanoparticles have been shown in recent research to be efficient against bacteria when combined with conventional antibiotics, particularly against multidrug-resistant pathogens like S. aureus and E. coli. (Vasil'kov et al. 2022, Elbehiry et al. 2019).

Ag nanoparticles' antibacterial activity is greatly increased when combined with pharmaceuticals, especially when it comes to drug-resistant bacteria (Yuwen et al. 2018). This combination has recently been studied as a possible tactic to combat bacteria' resistance to antibiotics. It was suggested that increasing antimicrobial activity may be achieved by binding to a number of antibacterial drugs. Ag nanoparticles have been used in a number of vancomicin experiments. Despite the fact that some authors assert superior results against both Gram-positive and Gram-negative bacteria (Kaur et al. 2019). Recent research indicates that the antibacterial activity of the nanomaterial is less effective against Gram positive bacteria than Gram negative bacteria. During World War I, the most common substance utilized to treat and prevent military diseases was silver (Esmaeillou et al. 2017).

When compared to particles made from other heavy metals, such gold, platinum, and zinc, AgNPs have demonstrated a high degree of antibacterial activity and a low level of cytotoxicity. They have the ability to adhere to cells, disrupt the function of enzymes, cause instability in cell membranes, and ultimately cause cell death. According to studies, AgNP can cause inflammation, cytotoxicity, genotoxicity, and DNA damage, all of which can lead to cell death. Long-term contact between a cell's membrane and its neural components can cause skin disorders and argyria disease, also known as "blue skin" (Tang and Zheng 2018).

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