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Study The Synthesis and Produce Silver Nanoparticles and Their Antibacterial Role (Subject Review)

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Annotation: Using materials with at least one dimension between 1 nm and 100 nm, nanotechnology is a field of technology that produces new goods and materials. Nanomaterials have only recently attracted the attention of researchers due to their distinct, important, and superior qualities that distinguish them from macroscopic materials. Their high ratio of surface to volume and the increased atom concentration at grain boundaries are two notable differences. Materials such as metal nanoparticles, nanomaterials made from carbon, and their composites have been widely exploited as novel antibacterial agents due to their small sizes, unique physical and chemical properties, and high particular surface areas. Silver nanoparticles are frequently used in sectors like biomedicine, pharmacy, and cosmetics due to their special antimicrobial properties. Silver (Ag) nanoparticles are the most widely used antibacterial nano-agent among the various engineered nanoparticles that have been used in antibacterial treatments because of their potent antibacterial efficacy and broad-spectrum antimicrobial qualities against a variety of bacteria, viruses, and fungi.

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

Introduction

In order to create new materials and products, the discipline of technology known as nanotechnology works with materials that have at least one dimension between 1 nm and 100 nm. Due to their distinctive, superior, and important qualities, nanomaterials differ greatly from macroscopic materials and have only recently attracted the attention of researchers. Their high surface-to-volume ratio and the greater number of atoms found at grain boundaries are two important differences. Nanomaterials play a crucial role in creating new technologies that can be applied to a variety of sectors, including physics, biology, biomedicine, pharmacology, cosmetics, and numerous product industries (Annamalai et al. 2016; Saleh et al., 2024).

Recently, the ability of nanotechnology to effectively cure bacterial infections has been demonstrated. An association between the development of mold and germs was established in 1870 by the English physician John Scott Burdon Sanderson. Soon later, in 1928, Alexander Fleming is credited with making the unintentional discovery of penicillin. Because most infectious infections were fatal at the time penicillin was initially used, it had a significant impact on antibacterial treatment.. As soon as penicillin was employed, it had an impact on Gram positive bacteria (Annamalai et al. 2016, Esmaeillou et al. 2017). Many bacteria strains have developed immunity in modern times as a result of the excessive use of antibiotics. Following the initial reports, numerous medications with powerful antibacterial, antifungal, and antiviral effects were created. Antibiotic overuse had two main consequences: first, it led to the development of multiresistant bacteria and a rise in microbial resistance, endangering the lives of numerous people (Annamalai et al. 2016, Esmaeillou et al. 2017; Saleh 2019; Saleh and Abbood 2020).

The immediate result was the need for innovative techniques to allow the production of new compounds with antibacterial properties while maintaining low toxicity levels suitable for medical applications. The most recent antibacterial medications were created in the 1980s. Since then, no noteworthy discovery has been announced. One of the first antibiotics, vancomycin has been used for more than 50 years to treat infections caused by methicillin-resistant Staphylococcus aureus. As bacteria evolve over time, new strains that are resistant to vancomycin start to arise. As a result, the creation of new medications is always required. One concept for enhancing medications is effect enhancement with nanoparticles, which permits the binding of metals, protein molecules, phospholipids, and antibodies (Esmaeillou et al. 2017).

Due to their tiny sizes, distinctive chemical and physical properties, and high specific surfaces, materials like metal nanoparticles (da Silva et al. 2020), metal oxide nanoparticles (Keshavarz et al. 2020), carbon nanomaterials (Alavi et al. 2020), and their composites have been widely used as new antibacterial agents. Due to their unique antibacterial qualities, silver nanoparticles have found extensive use in industries like biomedicine, pharmacy, and cosmetics (Yuwen et al. 2018).

It has been discovered that compared to other metallic particles, silver nanoparticles are more biocompatible, less poisonous, and have superior antibacterial qualities. Applications that are more antibacterially targeted can be based on the observations and facts regarding AgNPs' broad-spectrum antibacterial activity. Ag nanoparticles are more effective than antibiotics at halting bacterial growth and are less likely to cause adverse side effects, according to more recent research (Annamalai et al. 2016, Yuwen et al. 2018).

Metal Nanoparticle Synthesis

The green approach, which includes a variety of chemicals and reagents, prokaryotic cells of bacteria, eukaryotic fungal organisms, plant extract, flowers, leaves, and plants, can be used to create metal nanoparticles. Additionally, we will examine physical methods that have previously been developed.

Green Methods

The employment of biological organisms including bacteria, mold, algae, and plants enables one-step synthesis. The reduction process uses the proteins and enzymes found in plants and microbes to create nanoparticles. Compared to chemical procedures, the green synthesis of metal nanoparticles is often less costly and uses more ecologically friendly substances. The reducing agent that transforms the metallic silver precursor into metallic nanoparticles is one of the plants that was previously discussed. Additionally, they offer a steady source of bioactive materials for the production of metallic nanoparticles. The process has little effect on the environment and can reduce the negative impacts (Rauwel et al. 2015).

In a recent work, silver nanoparticles were produced using the rind extract of Garcinia mangostana. 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 combined and sieved to produce uniformly sized particles. Fifty milliliters of distilled water were used to suspend 1.5 grams of the collected particles for 15 minutes at 50 to 70 degrees Celsius. One of the difficulties with the green technique is controlling the size and shape of the nanoparticles. Temperature is believed to have the largest influence on material synthesis (Nishanthi et al., 2019). Lower temperatures did not result in the production of nanoparticles, the researchers discovered. However, when the temperature was increased to 80 C, the authors saw the formation of metallic nanoparticles. Particle development is also restricted at temperatures near 100 C because to the exceedingly high reaction rate. 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

Nanoparticles are made using a variety of chemical processes, including chemical decrease, light-induced reduction, irradiation methods, microwave-assisted manufacturing, UV-initiated photo decreasing, micro emulsion, and electrochemical synthetic technique (Raza et al. 2016).

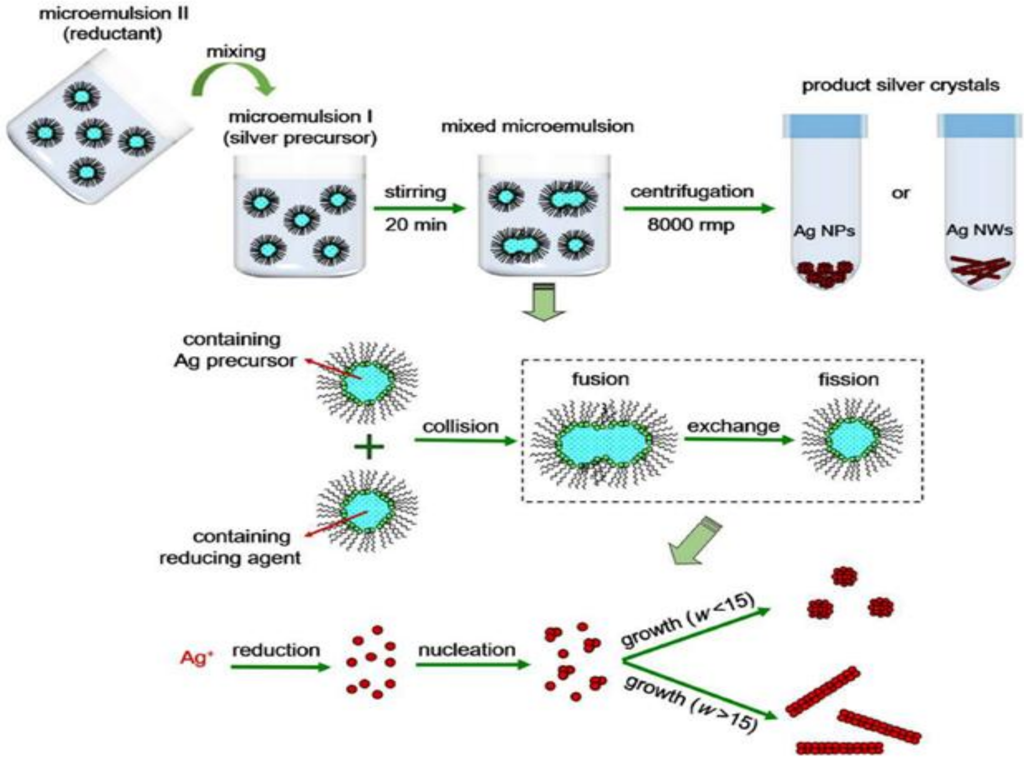

Figure 1. Diagram of the reaction using the reverse microemulsion technique.

The authors propose a multi-step synthesis procedure that includes the following steps: (1) the collision and exchange of reactants between water droplets; (2) the nucleation reaction; (3) the growth of silver nanoparticles; (4) the diffusion of surfactant molecules onto the nano surface; (5) the dispersion of water droplets in an oil phase; (6) the stabilization of the water/oil interface by surfactant molecules; and (7) the mixing of the two microemulsions (Feng et al. 2018).

The methods mentioned by Turkevich and Khan are among the most often employed. The Turkevich methods include the following actions: 49 mL of ultra-pure water is used to dissolve 9 mg of AgNO3, and the liquid is then heated to 100 °C while being agitated. The mixture is allowed to reach room temperature after forty-five minutes. After adding one milliliter of a 38.8 mM sodium citrate solution, the mixture is centrifuged for an hour at 500 rpm to remove any remaining big particles. Following formation, the pure and stable Ag nanoparticles are stored 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

The two most crucial techniques for physical synthesis are laser ablation and evaporation-condensation. The uniform distribution of nanoparticles and the lack of solvent contamination are two benefits of employing a physical method as opposed to a chemical one. The evaporation-condensation method can be used to produce minuscule nanoparticles. 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 researchers used millisecond laser pulses at 800 nm to generate the nanospheres (20–50 nm) in water (Iravani et al. 2014).

Antibacterial Role

Pharmaceutical companies have spent the last 30 years creating new antibiotics that are better at stopping the construction of bacterial cell walls, the production of proteins, and the replication of DNA. Despite these advancements, there is still a high death rate from bacterial infections because of the rise in antibiotic resistance. One of the biggest issues facing world healthcare is bacterial resistance to traditional antibiotics (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).

Silver (Ag) nanoparticles are the most widely used antibacterial nano agent among the variety of engineering-created nanoparticles that have been used in antibacterial treatments because of their potent antibacterial efficacy and broad-spectrum antimicrobial qualities against a range of pathogenic microorganisms, 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, epidermal burns, wounds, and wart removal are frequently treated with medications that include silver, such as silver nitrate and silver sulfadiazine (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).

Combining Ag nanoparticles with medications significantly increases their antibacterial efficacy, particularly against drug-resistant bacteria (Yuwen et al. 2018). Recently, this combination has been investigated as a potential strategy to counteract antibiotic resistance in microorganisms. It was proposed that binding to several antibacterial medications could boost antimicrobial activity. Several studies using Ag nanoparticles have been conducted on vancomicin. Even yet, some authors claim better outcomes against both Gram-negative and Gram-positive germs (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.

Silver was the most frequently used material in preventing and treating military infections during the First World War (Esmaeillou et al. 2017).

When compared to particles made from other heavy metals, such gold, platinum, and zinc, silver nanoparticles have demonstrated a high level 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. Studies have shown that AgNP can kill cells by causing DNA damage, cytotoxicity, genotoxicity, and inflammation. 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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