Journal of Applied Science and Education, 2024,
Vol. 04, Iss. 02, S. No. 072, pp. 1-8
ISSN (Online): 2583-1372

Advances in Synthesis Approaches and Biological Applications of Silver Nanoparticles: A Systematic Review

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How to cite this paper: P. C. Dhabas, K. Tanwar, A. K. Kakodia, S. Singh and S. Jain, "Advances in Synthesis Approaches & Biological Applications of Silver Nanoparticles: A Systematic Review," *Journal of Applied Science and Education (JASE)*, Vol. 04, Iss. 02, S. No. 072, pp 1-8, 2024.

https://doi.org/10.54060/a2zjournals.jase.72

Received: 06/06/2023
Accepted: 16/05/2024
Online First: 13/06/2024
Published: 25/07/2024

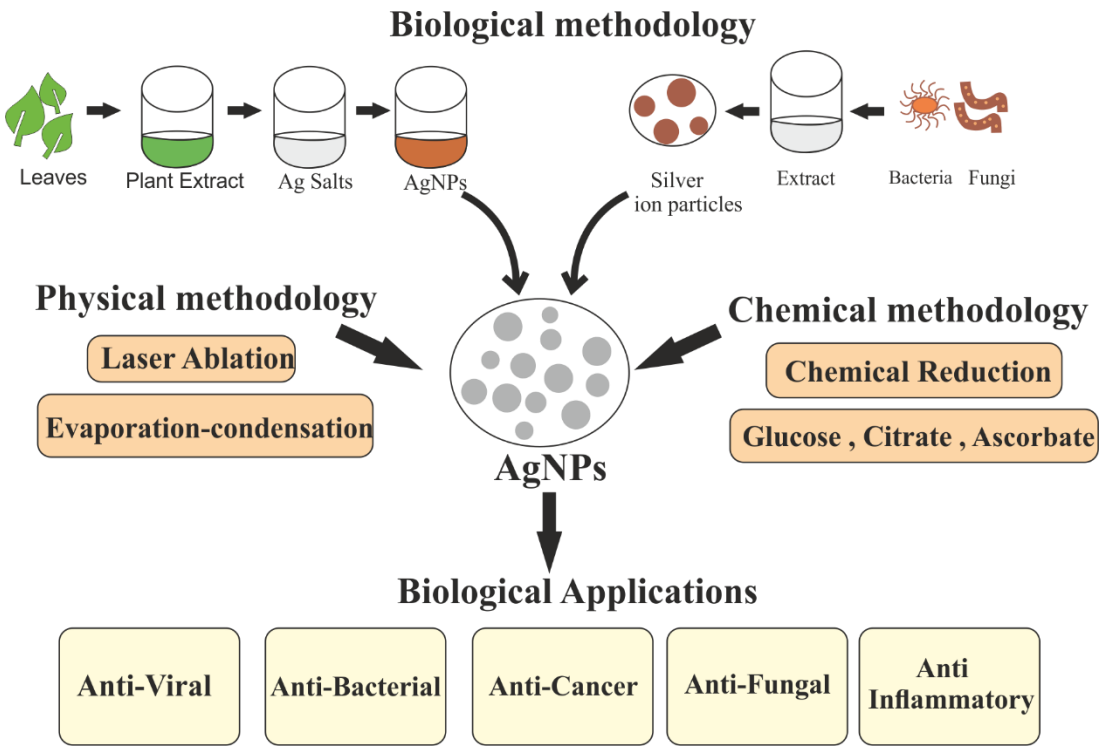
Abstract

The need for silver nanoparticlesor AgNPs is rising quickly across a wide range of industries, including healthcare, pharmaceuticals, food, cosmetics, and medicine. Owing to its many functions, it has been applied in a variety of settings, including the food industry, medical devices, housekeeping, wound dressing, orthopaedics, and diagnostics. It has also been utilised as an anticancer agent. These microscopic particles can potentially be put to use for a plenty of purposes and have the ability to alter their physical, chemical, and biological properties. Three discrete approaches emerge for preparing AgNPs: chemical, biological, and physical. Of the three approaches, the biological approach is proven to be the most straightforward, environmentally friendly, marketable, and one-step procedure; it also requires the least amount of force, high pressure, or temperature. Ag NPs have been shown to halt the expansion and proliferation of numerous bacteria by linkingAg/Ag+utilizing the biomolecules that thrive in the cells of microbes.

Keywords

Nanoparticles, silver nanoparticles (AgNPs), biological approach

Graphical Abstract



1. Introduction

A class of materials known as silver nanoparticles (AgNPs) has diameters between 1-100 nm. The zeal for the research of AgNPs in relation to their diverse behaviours has expanded recently due to their distinctive and appealing chemical, physical, and biological attributes. Because silver is innocuous to humans and has antimicrobial properties, it is favoured as a nanoparticle.[1-3]Owing to its numerous purposes, AgNPs have successfully implemented to a variety of situations along with wound dressing, orthopaedic surgery, the food industry, medical supplies, and antibacterial qualities. It also serves as a cancer prevention agent.[4]

To meet the criteria of AgNPs, they are synthesized using a variety of techniques. Physical and chemical approaches are typically deemed to be treacherous and expensive.[5-6]However, the biologically produced nanoparticles offer high solubility, greater yield and a high degree of stability. Amongst the three methodologies, the biological methodology is demonstrated for being a facile, secured and a straightforward procedure that is unlikely to require hazardous chemicals or high temperatures, pressures, or forces.[7]

Following the creation of these nanoparticles, it is crucial to characterize these particles. Prior to employing nanoparticles for the purpose of medical treatment, human welfare, or the healthcare sector, it is of the utmost importance to characterize the generated nanoparticles in order to identify whether any of them pose a threat to safety.[8]Studying a nanomaterial's characteristic properties such as its shape, aggregation, solubility, surface area and particle size and distribution is fundamental. The following analytical methods are utilized for examining these AgNPs: ultraviolet-visible spectroscopy, the FTIR, SEM,

TEM , DLS method, XRD etc.[9-10] The characterization techniques are exhibited in Figure 1.

The size and shape-dependent characteristics of AgNP's make them intriguing for many kinds of applications, including detection to optics, data storage and antibacterial action. Furthermore, the catalytic activity in addition to their size, is also influenced by their shape, structure and chemical and physical environments. Controlling the size and size variation is therefore an essential requirement.

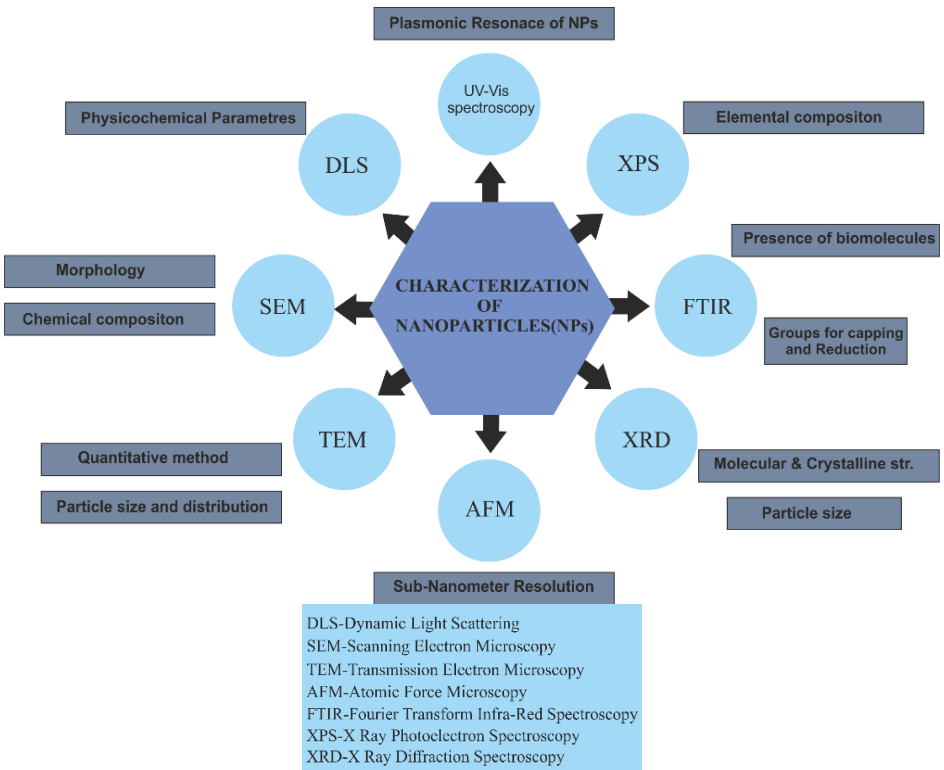


Figure 1. Characterization of Nanoparticles

2. Synthesis of Silver Nanoparticles (AgNPs)

2.1. Physical Methodology

In this practice, evaporation-condensation is normally employed for manufacturing nanoparticles; this process can be done at atmospheric pressure in a tube furnace [11]. Nevertheless, there are a number of downsides to synthesize AgNPsin a tube furnace as it demands a plenty of space, renders extensive use of energy to elevate the degree of temperature surrounding the source material and attains thermal equilibrium over a long duration of time.

Metallic bulk substances are subjected to laser ablation to produce AgNPs. The attributes of the generated fragments of metal and the extent of efficiency of ablation rely on several different aspects among which is the laser's wavelength when it hit a metallic target and how long its pulses last, the length of the ablation process, the liquid medium's potency, with as well as without surfactants and the laser fluence.

The laser fluence is among the most essential variables. A discovery has recently been figured that the nanoparticle's average dimensions usually rises with increasing fluence of laser and often reaches its lowest point for fluencies that refrain from going beyond the cut-off point for laser breakdown.

2.2. Chemical Methodology

AgNPs are frequently synthesized chemically utilizing organic solvents or water. Reductants notably borohydride, glucose, citrate, and elemental hydrogen are frequently adopted. In a liquid phase, silver ions (Ag+) experiences reduction which generally generates colloidal silver, which has particles within the nanoparticle range.

First, distinct complexes constituting silver ions (Ag+) undergo reduction which guides to the emergence of silver atoms (Ag0). This is succeeded by oligomeric development of clusters. Colloidal Ag particles are ultimately formed as an outcome of these clusters. Utilizing protecting agents is vital for regulating dispersive nanoparticles throughout the process to formulate nanoparticles. Safeguarding the nanoparticles with substances that may adhere to their surface and prevent them from clumping together is the most popular tactic.

2.3. Biological Methodology (Green Approach)

The utilisation of green synthesis to produce silver nanoparticles is favoured due to its environmental friendliness, profitability, and one-step nature, since it bypasses the need for unsafe substances, high temperatures, pressure, and force [12]. Various substances such as plant extract, bark, fungi, roots and so on are utilized in the creation of nanoparticles.

Different bacteria play a part in this biological approach such as E. coli , Lactobacillus strains , Bacillus licheniformis and Pseudomonas stutzeri AG259. Fusarium oxysporum and Typha angustifolia are a few fungi which are employed in this green approach [13]. Regulated particle dimension and shape appears to be attainable with biological approaches, which is profitable for a variety of applications in medicine [14]. The proximity of enormous range of biological specimens, a shorter reaction time, stability, and the swift solvability of nanoparticles in aqueous media are a few additional advantages of biological methodologies [15].

The shape and composition of AgNPs highly impact their biological activity. Truncated-triangular and tiny AgNPs tend to be successful and possess exceptional characteristics with respect to size and structure.In order to attain mastery over morphological structures an overabundance of potent reducing agent like sodium borohydride (NaBH4) is employed.

3. Use of AgNPs in Biological field

Because of their idiosyncratic traits, AgNPs exhibits a broad spectrum of therapeutic and biological benefits: anti-cancer, antiviral, anti-inflammatory and anti-fungal properties. Few of the biological applications are depicted in figure 2.

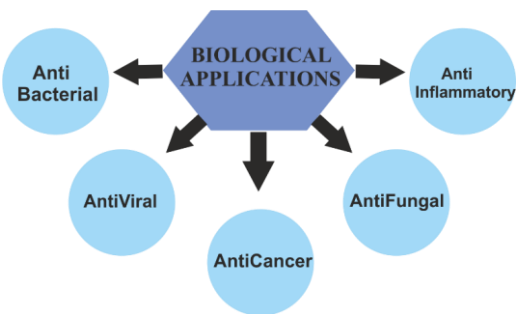


Figure 2. Biological applications of AgNPs

3.1. Antibacterial Action

As silver is benign to humans and possesses antimicrobial properties, it has been chosen as a nanoparticle. AgNPs promise to be a substitute for antibiotics. AgNPs are viewed to be prospective antibacterial representatives owing to its crystalline surface

structure and elevated surface-to-volume ratios [17].

Sondi et al. noted that AgNPs were effective against Escherichia coli in terms of antibacterial activity. AgNPs treated E. Coli cells, demonstrating the formation of pits in the bacterial cell death process and AgNP accumulation in the bacterial cell wall [16].

To create AgNPs, four different saccharide variants were used. Against both Gram-positive and Gram-negative bacteria, they demonstrated potent bactericidal and antibacterial properties. Furthermore, a thorough investigation of the antibacterial efficacy of AgNPs against yeast, S. aureus, and E. coli was conducted. The results suggest that S. aureus very little responded to the low concentrations of yeast and E. coli, whereas both bacteria displayed total restrictions [16, 18].

When contrasted with AgNPs derived from the culture phase of bacteria (B-AgNPs), AgNPs generated by fungal preparations as reducing substances (F-AgNPs) exhibited more effective antibacterial properties against S. aureus [19].

3.2. Antifungal Action

People with weakened immune systems are more susceptible to infections caused by fungus. The number of antifungal medications in the market is exceptionally small. Thus, the development of antifungal substances that ought to be safe, biodegradable and ecologically accpetable is inevitably and critically required [20]. Currently, AgNPs are efficient anti-fungal drugs that combat a range of fungal-related medical conditions.

AgNPs that were biologically built illustrated improved antifungal properties when paired with fluconazole towards numerous distinct fungi [22]. By preventing conidial germination, the biologically derived AgNPs displayed potent antifungal efficacy over Bipolar is sorokiniana [21].

3.3. Anti-inflammatory Action

The scenario where a portion of body swells or grows warmer is called inflammation. Tissue initiates inflammation as a first line of resistance against foreign particles, and this response is reinforced by a greater production of cytokines that are pro-inflammatory [23]. AgNPs are one of multiple medicines for inflammation that have lately become significant contenders in the anti-inflammatory domain.

The soothing action was detected in rats as described by Bhol et al. [24]. AgNP-treated rats demonstrated dose-dependent enhancements in their visual characteristics and quick rehabilitation. AgNPs additionally demonstrated remarkable antibacterial capabilities, an overall reduction in wound inflammatory disorders and alterations of fibro genic cytokines.

3.4. Antiviral Action

Since viral infections and diseases are ubiquitous round the world, it is of the utmost importance that we create antiviral medications which offer significant outcomes [25].

The very first mechanistic investigation showing anti-HIV early on throughout the transmission of virus's cycle has been reported by Lara et al. [27]. Polyvinyl pyrrolidone (PVP) coated AgNPs halted dissemination of HIV-1 strains whose cells are cell-free and cell-associated. AgNPs exhibit effective inhibitory responses against the viruses that cause hepatitis B (HBV).[26]

3.5. Anticancer Activity

Throughout our lives, one in three individuals might get cancer. In essence, cancer is a consequence of uncontrolled cell development in particular parts of the body. Even though numerous kinds of chemotherapy medications are being incorporated to act towards multiple cancer kinds. Development of technological advances to prevent systemic side effects is therefore mandatory. Numerous investigations have been performed to investigate the optimistic outcome of AgNPs. By encasing a

therapeutic chemical in a nanoparticle and using it as a medication delivery system, AgNPs can exclusively target particular cells or malignancies at the exact site [28].

4. Challenges for AgNP's in Cancer treatment

AgNPs are utilized as a complementary treatment owing to their site-specificity, less noxiousness, improved efficacy, and additional virtues. However, they posses certain shortcomings in cancer therapy. These comprise physiological hurdles, retention effect (EPR), carrying capacity constraints, increased permeability and nanoparticle variability [29].

5. Conclusion

The need for silver nanoparticles or AgNPs is rising quickly across a wide range of industries, including healthcare, pharmaceuticals, food, cosmetics, and medicine. The synthesis and bio applications of silver nanoparticles had been covered in this review with a particular emphasis on cancer prevention initiatives. Three kinds of methodologies are incorporated for the engendering of AgNPs. These are physical , biological and chemical approaches. Amongst the three, the biological one is chiefly employed as it is non threatening and sustainable. When it relates to cancer treatment, it's been determined to be reliable and site-specific. Thus, it could potentially concluded that AgNPs are easy to comprehend, secure, and highly efficient therapy for a wide range of maladies.

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