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Silver nanoparticles as a new generation of antimicrobials –a review

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ABSTRACT

The major challenge the world is facing today is the mode of treatment of pathogenic bacteria which have become resistant to the existing antibiotics. Day by day, the resistance to existing antibiotics or drugs is increasing for one or other reasons. This increasing incidence of antibiotic resistance among the microbial organisms necessitates an alternate therapy to curb the resistant infections microorganisms. A new approach to prevent or combact microbial pathogens is by the use of silver nanoparticles especially synthesized with the help of natural medicinal plants. The synthesized silver nanoparticles are generally characterized by UV-vis spectroscopy, scanning electron microscopy (SEM), Transmission electron microscopy (TEM), Fourier transform infrared spectroscopy (FTIR), Zeta potential, X-ray diffraction (XRD), etc.

Keywords: Silver nanoparticles, medicinal plants, nanotechnology, structural characterization

INTRODUCTION

Nanotechnology is now creating a growing sense of excitement in the life sciences especially biomedical devices and Biotechnology [1]. Nanoparticles exhibit completely new or improved properties based on specific characteristics such as size, distribution and morphology. The silver nanoparticles have various and important applications. Historically, silver has been known to have a disinfecting effect and has been found in applications ranging from traditional medicines to culinary items. It has been reported that silver nanoparticles (SNPs) are non-toxic to humans and most effective against bacteria, virus and other eukaryotic micro-organism at low concentrations and without any side effects [2]. Moreover, several salts of silver and their derivatives are commercially manufactured as antimicrobial agents3. In small concentrations, silver is safe for human cells, but lethal for microorganisms [4]. Antimicrobial capability of SNPs allows them to be suitably employed in numerous household products such as textiles, food storage containers, home appliances and in medical devices [5]. The most important application of silver and SNPs is in medical industry such as tropical ointments to prevent infection against burn and open wounds [6]. Biological synthesis of nanoparticles by plant extracts is at present under exploitation as some researchers worked on it [7,8] and testing for antimicrobial activities [9, 10, 11]. For the last two decades extensive work has been done to develop new drugs from natural products because of the resistance of micro-organisms to the existing drugs. Nature has been an important source of a products currently being used in medical practice [12]. The present study is a review of silver nanoparticles (medicinal plant mediated) a new generation of antimibrocials to combact microbial pathogens.

Medicinal plants: an alternative source as antimicrobics:

A new hope of treating such multidrug resistant infections came from medicinal plants since nature is the only source to provide a variety of chemical compounds that can be used for new drug discovery. A number of secondary metabolites like phenols, flavonoids, glycosides, alkaloids, saponins, triterpenes, etc. produced by plants are pharmacologically active. The added advantages of using natural products therapeutically is they are safe, economical, and with lesser side effects. The plant extract can be used singly or in combination with antibiotics or other plant extracts or some chemicals i.e. combination therapy. This was the next approach to combact the multidrug resistant bacteria. However, the development of drug resistant strains is rising alarmingly and the search for new and novel ways of fighting the drug resistsnce mechanism and win-win or re-emerging microbes goes on.

Need for novel approach:

Increasing resistance against antibiotics is a burning health problem. So there is an urgent and dire need to improve the existing drugs or find new, novel strategies to overcome this problem. Reducing the particle size is an efficient and reliable tool to endeavor. The therapeutic applicability of silver and medicinal plants in treating bacterial infections is already well known. Recently, synthesis of silver nano particles (SNPs) with the help of medicinal plants is attempted; the reduction of silver to nano size is accomplished by the secondary metabolites present in the medicinal plants. Nano particles, generally considered as particles with a size of up to 100 nm, exhibit completely new or improved properties as compared to the larger particles of the bulk material that they are made up of.

There are various methods of synthesizing silver nano particles such as ultraviolet irradiation, aerosol technologies, lithography, laser ablation, ultrasonic fields, heating and electrochemical reduction, photochemical reduction and application of reducing chemicals like hydrazine hydrate and sodium citrate, sodium borohydride, formaldehyde, polyethylene glycol, glucose, etc. but these techniques are expensive and sometimes hazardous chemicals are involved in their synthesis which is harmul to the environment also. To circumvent this many biological systems like bacteria, fungi, yeast, cyanobacteria, actinomycetes and plants have been used. But the best one appears to be the use of plants. Any part of the plant can be utilized for the synthesis of silver nanoparticles. The use of various parts of plants for the synthesis of nanoparticles is considered as a green technology as it does not involve any harmful chemicals. The synthesis of silver nanoparticles by means of using aqueous extracts of medicinal plants is simple, efficient, eco friendly, inexpensive, safe and it does not require any sophisticated instrumentation.

Synthesis of silver nanoparticles – medicinal plants mediated:

The first step is to make aqueous plant extract, which is usually done by boiling the plant material in distilled water. The time generally varies from 2 to 15 minutes. This plant extract is added to $AgNO_3$ and the moment the two solutions are mixed the formation of silver nano particles begins. As soon as the plant extract is added to $AgNO_3$, the colour of $AgNO_3$ changes from colourless to yellow, brown, orange indicating the synthesis of silver nano particles in the aqueous solution. However, this time duration changes from plant to plant. The initiation of formation of silver nano particles varies from few minutes to few hours after which, there is slight variation in its formation but normally the procedure is continued for 24 h. There are many factors which affect the formation of silver nano particles. The concentration of the aqueous plant extract plays an important role in the formation of silver nano particles. The higher concentration of the plant extract will lead to the formation of more silver nano particles; The concentration of $AgNO_3$ also influences the formation of silver nano particles but higher concentration of $AgNO_3$ will produce larger silver particles and vice versa. The other factors that influence the shape and size of silver nano particles are pH and temperature. Large particles are formed at lower pH whereas at higher pH, highly dispersed and smaller nano particles are formed.

Mechanism of antibacterial activity of silver nanoparticles:

The antibacterial activity exhibited by silver nano particles depends on $AgNO_3$ concentration. It is inversely proportional i.e. less metal concentration more is the activity and vice versa. This is because smaller particles have larger surface area available for interaction and will give more bactericidal effect than the larger particles. Nano particles exhibit completely new or improved properties based on specific characteristics such as size, distribution and morphology. The cell membrane of microorganisms is negatively charged and silver nano particles are positively charged and when these positively charged silver nano particles accumulate on negatively charged cell membrane, it brings about a substantial conformational change in the membrane and it ultimately loses permeability control which leads to cell death.

Mubarak Ali et al. stated that once silver nano particles enter the bacterial cell, they would interfere with the bacterial growth signaling pathway by modulating tyrosine phosphorylation of putative peptides substrates critical for cell viability and cell division. The nanoparticles release silver ions in the bacterial cells, which enhance their bactericidal activity [13,14]. Mahendra et al[15] stated that silver nano particles preferable attack the respiratory chain, cell division finally leading to cell death.

According to Amro et al.[16] metal depletion may cause the formation of irregularly shaped pits in the outer membrane and change membrane permeability, which is caused by progressive release of lipopolysaccharides and membrane proteins. Or perhaps DNA loses its replication ability and expression of ribosomal subunits proteins as well as some other cellular proteins and enzymes essential to ATP production becomes inactivated[17]. The other mechanism proposed by Danilczuk et al. [18] and Kim et al.[19] is the formation of free radicals which subsequently induces membrane damage leading to efficient antimicrobial property of silver nano particles. The other mechanism proposed is involvement of interaction of silver nano particles with biological macromolecules such as enzymes and DNA through an electro-release mechanism. The nanoparticles get attached to the cell membrane and penetrate inside the bacteria. The bacterial membrane contains sulfur containing proteins and the silver nanoparticles interact with these proteins in the cell as well as with the phosphorus containing compounds like DNA. Their interaction may cause damage to DNA and proteins resulting in cell death. Ag^+ binds to functional groups of proteins, resulting in protein denaturation. The silver nano particles show efficient antimicrobial property due to their extremely large surface area, which provides better contact with microorganisms. It is reasonable to state that the binding of the nano particles to the bacteria depends on the interaction of the surface area available. Smaller particles having a larger surface area available for interaction will have a stronger bactericidal effect than will larger particles

Application of silver nanoparticles:

Antimicrobial capability of SNPs allows them to be suitably employed in numerous household products such as textiles, food storage containers, home appliances and in medical devices. The most important application of silver and SNPs is in medical industry such as tropical ointments to prevent infection against burn and open wounds. Silver nano particles are reported to have many therapeutic uses. There are reported to possess anti-viral, antibacterial, antifungal, anti-parasitic, larvicidal activity, and anticancer properties. Due to strong antibacterial property silver nano particles are used in clothing, food industry, sunscreens, cosmetics and many household appliances. Few studies have showed that silver nanoparticles kill fungal spores by destructing the membrane integrity.

Characterization of silver nanoparticles:
The synthesized silver nanoparticles are generally characterized by UV-vis spectroscopy, Scanning electron microscopy (SEM), Transmission electron microscopy (TEM), Fourier transform infrared spectroscopy (FTIR), Zeta potential, X-ray diffraction (XRD), etc.

A] Ultraviolet – Visible (UV-VIS) spectroscopy:
UV-vis spectroscopy is a valuable tool for structural characterization of SNPs. It is a fundamental technique to ascertain the formation of stable metal nanoparticles in aqueous medium. It is well known that the optical absorption spectra of metal nanoparticles are dominated by surface plasmon resonances (SPRs) that shift to longer wavelengths with increasing particle size. Also, it is well recognized that the absorbance of Ag NPs depends mainly upon size and shape. In general, the number of SPR peaks decreases as the symmetry of the nanoparticle increases. The position and shape of the plasmon absorption depends on the particles' size and shape, and the dielectric constant of the surrounding medium. The appearance of SPR peaks at 446 nm provides a convenient spectroscopic signature for the formation of silver nano particles.

B] Scanning electron microscopy (SEM) studies:
The SEM analysis is employed to characterize the size, shape, morphology and distribution of synthesized silver nano particles.

C] Transmission electron microscopy (TEM) studies:
TEM measurements are conducted in order to estimate the particle size and size distribution of the synthesized silver nano particles. The plant extract should be sufficient enough to be coated on the synthesized silver nano particles, otherwise aggregation of particles is accelerated and the particles are not sufficiently stabilized.

D] Fourier transform infrared spectroscopy (FTIR) studies:
FTIR measurements are carried out to identify the possible biomolecules responsible for reduction, capping and efficient stabilization of silver nano particles and the local molecular environment of the capping agents on the nanoparticles.

E] Zeta potential:
Zeta potential is an essential parameter for the characterization of stability in aqueous nano suspension. A minimum of + 30 mV zeta potential values is required for indication of stable nano suspension Higher zeta potential indicates greater stability of the synthesized silver nano particles.

F] X- ray diffraction (XRD) studies:
The XRD has proven to be a valuable research tool to prove the formation of silver nano particles, and to determine the crystal structure of the prepared silver nano particles and to calculate the crystalline particle size. Mounting evidences suggest that silver nanoparticles act as promising antimicrobial agents and may emerge as an alternative to conventional antibiotics. They could be of immense use in the medical field for their efficient antimicrobial function.

CONCLUSION

The present review describes silver Nanoparticles synthesized by medicinal plants can be used as a new novel source of antimicrobics to combat multiple drug resistant tough microorganisms and also can be therapeutically utilized to combat other diseases and disorders. Silver nanoparticles have good antimicrobial activity against different microorganisms. It is confirmed that silver nanoparticles are capable of rendering high antifungal efficacy and hence has a great potential in the preparation of drugs used against fungal diseases.

Conflicts of interest: The authors stated that no conflicts of interest.

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