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Green Synthesis of Silver Nanoparticles for Various Biomedical and Agro Industrial Application

Abaysew Ayele*, Rita S. Mujmdar, Tesfaye Addisu, Yohannes Woinue

School of Basic Science and Research, Biotechnology Department, Shrada University, Greater Noida – 201 310, Uttar Pradesh, India.

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ABSTRACT

Silver nanomaterials have been integrated into industrial, biomedical and agricultural application, including biosensor, anti-microbial, anti-tumor, drug delivery, waste treatment, coated fabrics and nano fertilizer. Nanoparticle possesses unusual character due to their large surface area to volume ratio and an extraordinary catalytic activity, electronic properties, optical properties and anti-microbial activity while they are constructed in atomic level. The unique and major task in the synthesis of nanoparticle is choosing of an advanced and ecofriendly method. Nevertheless, physical and chemical methods of synthesis of nanoparticles are too expensive and environmentally unsound. In this study, the green synthesis of nanoparticle's production methods was evaluated on the basis of various literatures. Currently, there is a better possibility of using green synthesis of silver nanoparticles, especially a plant, bacterial and fungal production of nanoparticles which is emerging as a novel ecofriendly technique. The growth rate of bacterial culture, the extract of plant secondary metabolite and mycelial surface area of fungus are the main comprehensible mechanism in green synthesis of silver nanoparticles. The silver nanoparticles, which are produced through green biosynthesis is safe and hold a better possibility to be administered for medical and agricultural usages. Over all we found that the fungal green biosynthesis of silver nanoparticles is considered more preferable and is excellently chosen in it in industrial level production.

1. Introduction

Of several nanostructure types, metal nanoparticles which have a high precise surface area to volume ratio and a high fraction of surface atoms, so have been attracting considerable attention and studied extensively because of their exceptional phytochemical features, including catalytic activity, electronic properties, optical properties, anti-microbial activity, and magnetic properties [1]. This is therefore well understood of the synthesis mechanism, determining of the crystal structure of silver nanoparticles is a vital point of views.

It was when it came to a traditional way, such as physical and chemical methods of synthesis silver nanoparticles are used to date. However, there is a growing need to using environmentally friendly biological synthesis of nanoparticles is better to in minimizing cost, labor and environmental hazards [2]. That's why, biosynthesis of silver nanoparticles uses them extensively and are the primary provider of environmental protection and human health care. The discharge of chemical agent toxicity effect has a worry in environmental policy. The silver nanoparticles, which are formed using chemical method may verify hazards in the field of their application in biomedical tools [3]. Physical methods need expensive equipment and large space for their setup. Even if the physical method of radiation has speed and no hazardous use of chemical agents, it has low yield and high energy consumption in addition to pulsed higher laser deposition [4, 5].

Among ecofriendly biosynthesis of silver nanoparticles, using of fungus is desirable for industrial level production since which have been secreted high amount of a bulk of metabolites or bioactive compounds in a short period of time and ease in down processing. Their mycelia that provide a much higher surface area than bacteria and allow high production of the desired products [6, 7]. However, understanding of the breakdown of bulk materials through extracellular bioactive compounds into nanoparticles is not yet explored too far [8]. While silver nanoparticles tools have an immeasurable advantage in human daily use, the industrialized production of the particles must be reasonably priced and environmentally sound.

*Corresponding Author:betre.auroun@gmail.com(Abaysew Ayele)

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2. Origin and Concept of Nanoparticles

The prefix "nano" derive from the Greek word "nanos" mean "dwarf" is a common word in literatures. The word "nano" donates one billionth of a meter or 10^{-9}. The word nanotechnology was coined by professor Norio Taniguchi of Tokyo Science University in 1974 to illustrate precision manufacturing of materials at the nanometer level [9]. And the concept of nanotechnology at the first time was illustrated by Richard Feynman in a lecture entitled "There's plenty of room at the bottom" at the American Institute of Technology in 1959. Although the size of nano in numerous, the range of nanoparticles include from 1 to 100nm and are commonly synthesized by using two strategies. Either top-down or bottom-up technical strategies [10].

Materials of bulk size have been shown constant physical properties due to its large size. However, diminution of the size of nanoparticles have a significant effect on physical properties which totally different from the bulk materials. Unlike bulk materials, nanoparticles have characteristic physical, chemical, electronic, electrical, mechanical, magnetic, thermal, dielectric, optical and biological properties [11, 12]. Nanoparticles effective over bulk materials due to their surface plasmon resonance (SPR), enhanced Rayleigh scattering and surface enhanced Raman scattering (SERS) in metal nanoparticles, quantum size effect in semiconductors and super magnetism in magnetic materials. Therefore, nanoparticles are considered as building blocks of the next generation of optoelectronics, electronics, and various antibiotics, chemical and biochemical sensors [13, 14]. Alongside this, the nature of nanotechnology is a multi-disciplinary area like bio-nanotechnology in the scientific world where the various researches take place [15].

3. Principle of Silver Nanoparticles (AgNPs)

Many researches have been investigated on different metallic nanoparticles such as platinum and palladium (Pt & Pd) [16]. Gold (Au) [17] and Silver (Ag) [18]. Due to their large surface area to volume ratio, silver nanoparticles more prefer an anti-microbial activity which provides high affinity to contact the body of microorganisms. Because of this fact, metallic silver nanoparticles can be applied in the fields of molecular medicine, textile fabrics, dental materials, water treatment, food packaging, bio-labeling-sensor and in wound healing purpose. Why the

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silver nano particles being a center of attraction in those biomedical and industrial and have preferred? since AgNPs possess low toxicity on human cell and good biocompatibility, low volatile and high thermal stability [19, -23]. Beside to that here is a concrete scientific evidence why AgNPs being a choice of producing nano silver coated biomaterials, Ag ions has long-term antibacterial activity, due to sustained ion release [24] and low bacterial resistance [25].

Silver nanoparticles are popular whereas it has been used as antibiotics, which intermediate by metallic ion (Ag^0). The metallic ions own mode of action and bactericidal effect, but not yet defined its biochemical pathway. However, it is suggested that the silver nanoparticles attach to the cell wall and restrict the permeability of ions resulting the cytosol discharge and cellular respiration defects [26]. On the other side there is a controversial scientific view regarding to nanoparticles which would bind to the protein functional groups and hinder the gene expression.

4. Biosynthesis of Silver Nanoparticles

There are several ways of metallic nanoparticle synthesis methods. To date physical, chemical and biological reduction approaches were engaged in the synthesis of metallic AgNPs [27-30]. Despite if those methodologies have been practiced in production of nanoparticles, a chemical agent toxicity effect has a worry in environmental policy. Even if the physical method of radiation has speed and no hazardous as of chemical agents, it has low yield and high energy consumption [31]. Unlike physical and chemical processing, biological synthesis is further favor in which the biological system provides an innovative research idea in nano scale materials production [32]. Numerous researchers suggested that using of biological synthesis of AgNPs, without using of expensive and hazardous chemical agents such as organic solvents and toxic reducing agent, is elegant to enhance environmentally friendly technologies. Consequently, biosynthesis strategies are very simple techniques and cost effect no prolonged time required as of chemical and physical procedures.

4.1 Synthesis of AgNPs using Bacteria

Nowadays, there is a growing need to develop eco-friendly process. Thus, using of plants [33] and microorganisms [34] are suitable techniques in synthesis of AgNPs. As a result, researchers have turned to biological synthesis because through this biological synthesis obtaining particles with good control on the size distribution than the other traditional methods in which difficult to obtain because depend of the adjusted the concentration of reacting chemicals and controlled the reaction environment. Thus, the nanoparticles could also be stabilized directly in the process by proteins metabolic pathway [35-37].

To date, several microorganisms from bacteria to fungi have been reported to synthesize inorganic materials either intra- or extracellularly, and thus to be potentially utilized as eco-friendly nano factories [38, 39].

Pseudomonas stutzeri AG259, isolated from silver mines, has been shown to produce silver nanoparticles and the bio reduction of Ag was also reported in Bacillus licheniformis [40, 41]. In Addition to that, some bacterial genera, like Bacillus, Arthrobacter, Pseudomonas and Escherichia, could induce the synthesis of silver nanoparticles [42].

4.2 Synthesis of AgNPs using Fungus

Although several bacteria used in the biological synthesis of AgNPs, the eukaryotic fungal kingdom has been known to secret higher number of bioactive compounds which made fungi more suitable in large scale biomass production in nano factories [43]. And also, the extracellular biosynthesis using fungi could also make down processing much easier than bacterial biosynthesis of nano silver particles. Many fungi have mycelia that provide a much higher surface area than bacteria and this area could be used to support the interaction of metal ions and fungal reducing agent thus enhancing the conversion of ions to metallic nanoparticles sufficiently. Which biosynthesis exceptionally able to easy scale up and economical feasible [44]. Due to this, many researches have in sighted and tend to fungi biosynthesis process. For instance, *Fusarium oxysporum* and *Verticillium species* [45, 46], *Aspergillus fumigatus* [47], *Trichoderma reesei* [48], *Aspergillus niger* [49], *Aspergillus flavus* [50] and *Penicillium fellutanum* [51]. Fungal spp. has been used commonly in this day for microbial production of silver nanoparticles. However, there is a certain limitation of scientific reports on the finding of novel fungi strains and elucidate mechanism of the biochemical pathway.

4.3 Synthesis of AgNPs using Plant Extract

For the last two decades, synthesis of sliver nanoparticles using bacterial and fungus were practiced. Currently, using of plant extract has promised in biological synthesis of metallic nanoparticles [52].

The plants have produced essential secondary metabolites during their growth like alkaloids, flavonoids, terpenoids and so on. Those pythochemicals are the crucial components and mandate the green synthesis of nanoparticles in reduction and stabilization of metallic ions [53]. As per parashara et al. has proved, small size of silver nanoparticles (10-20 nm) were built by reducing the silver nitrate salt with that of Jatropha curcas extracts in 4 h.

According to this study plant extract has potential to reduce the metallic salts to nano ions in short duration of time along with their desirable size and shape. However, the sample of extract might need heat activation to temperature of 85 °C, which would be fairly costly if high volumes are required in industrial scale production.

4.4 Key Factors Affecting and Governing Biosynthesis of AgNPs

It is suggested that different parameters affect the optimum production of silver nanoparticles in biological system. However, the factors which affect the biosynthesis of AgNPs is fluctuate depending upon the kingdom, species and strains that would have been used. In former studies on the biological synthesis of silver and gold nanoparticles using bacteria [54] and fungi [55]. the time required for completion of the reaction ranges from 24 to 120 h, while the 24 h incubation exhibited maximum synthesis of silver nanoparticles.

Despite the Physio-chemical parameters effect on bacterial different from the fungi, temperature (T^0), incubation time (t), pH and concentration are the predominant factors in the biological synthesis of silver nanoparticles [56-59]

In the existing study, NADH is the main governing factor is synthesis of AgNPs using Aspergillus terreus. As Guangquan et al., 2012 have been issued that the dialyzed cell filter is induced by NADH and recover the reaction at 440 nm. This result indicated that NADH dependent reductase is might be the key factor in the synthesis of silver nano particles (AgNPs) using *Aspergillus terreus*.

5. Biological Application of AgNPs

Because of their unique molecular arrangement and structural alignment, AgNPs have many applications in biological, agricultural, industrial and biomedical division. Based on the preceding review, silver nanoparticles have been realized on in household utensils, health care industry, and in food storage, environmental, and in biomedical applications, such as a biosensor, anti-microbial, anti-viral, anti-tumor, anti-inflammatory, drug delivery, dental material, textile nano painting [60-65].

5.1 Nano-Coated Biomedical Tools and Fabrics

Silver salt was used to as antimicrobial before a century and was very well known effective in treatment of bacterial infection for wound healing. However, its function in the nano size level is not yet commonly understood and the toxic effect of silver nano particles has not been reported in the literatures [66, 67].

Antibiotic resistance strains are emerging this year and it is compulsory search out the broad spectrum against pathogens. Updated reports reach out that AgNPs have an inhibitory effect towards many microorganism strains commonly apply in medical and industrial processes. Silver nano particles have high antimicrobial activity against Gram negative and Gram-positive bacteria [68]. Therefore, those bio materials coated with AgNPs have a strong bactericidal effect on varieties of application, including wound healing, catheters, dental work, skin ointments, silver-impregnated polymers, silver-embedded fabrics, coatings for medical devices and water treatment filter [69-72].

Nano scale materials fully realized their optical, catalytic and antimicrobial activity as per the size and shape of the particles vary [73]. When the size of the metal nano particles is much diminished, its antimicrobial activity against pathogenic bacterial is strong elicited [74].

Thus, the properties of AgNPs will be effective on the verities of nanomaterials including medical device and industrial tools when it has been well investigated the atomic structure and optical properties of nanoscale particles.

5.2 Nano-Fertilizer

The fertility of agriculture soil has depleted against to the potential production of yield as long as the world population growth. Due to starvation of the soil fertility, it is suggested apply soil nutrition to enhance growth germination and yields of different substantial crops. Nano coated nitrogen fertilizer, such as Nano bentonite and Nano active coat does dramatically upturn the absorption and sped up the transportation biochemical pathway of the rice [75].

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On the hand, silver nanoparticles (SNP) in 25ppm concentration as of fertilizer had studied and found out the result, in which significantly improved above the average of the growth and yield quality of the grain wheat, but not in 75 ppm concentration [76].

5.3 Nano Oncology (Anti-cancer)

Induced tumors are proliferated, uncontrolled and leading to morbidity of the cells if could not treat at a target site of a chemical metabolism pathway of cancerous. Today, Nano type medicating is emerging and able to deregulate the expression of the oncogene proteins [77, 78]. Nanoparticles are applied in target drug discovery and drug delivery of cancer cell since they have very fine particles along their anti-cancer, anti-biotic, anti-allergic and anti-inflammatory properties. Based on recent studies, silver nanoparticles (AgNPs) was tested on different cancer cell line like MCF-7 cell, which induce a high cytotoxic effect as the concentration of the particles has increased. Resulting, prodigious morphology and condensed chromatic were recorded. Complete mortality rate on cancer cell line was observed in 50ug.ml of silver nanoparticles [79]. Having that non cytotoxity of normal cell, those biosynthesis of silver nanoparticles is promising in conjugating of drug delivery and gene therapy. In fact, that to date many researches have been conducted and gotten promising insight as descried in Table 1.

Table 1 Silver nanoparticles against cancer cel

AgNPs synthesis rout	Tested cancer cells	Ref.
Leave extract-*S. grandiflora*	Breast cancer cell line-MCF-7	[80]
Plant dandelion-*Taraxacum officinale*	Human liver cancer cells (HepG2)	[81]
Plant Extract-*Commelina nudiflora* L	HCT- 116 colon cancer cells	[82]
plant extracts of guava and clove	Human colorectal adenocarcinoma, the human kidney, human chronic myelogenous, leukaemia, bone marrow, and human cervix	[83]
Plant Extract-Nostoc linckia	MCF-7	[84]
Chemical synthesis	A549 (Human lung carcinoma), HeLa (Human cervical adenocarcinoma), MCF7 (Human breast adenocarcinoma), MDAMB231 (Human breast adenocarcinoma), and SKBR3 (Human breast adenocarcinoma) cells	[85]
Plant Extract-ethanolic extract of rose (*Rosa indica*) petals	Human colon adenocarcinoma cancer cell line HCT 15	[86]

5.4 Biosensor

The price of silver (Ag) is much cheaper than that of gold (Au) for using it as reference and counter electrode accepter in biological catalytically activity or electrochemistry and as silver paint for printed electrical circuit boards [87]. Due to their catalytically properties, silver nanoparticles, is important in molecular diagnosis and biomedical researches. The studies have showed that silver nanoparticles were applied in conjugating of oligonucleotides probe to target DNA hybridization because the DNA duplex will be easily differentiated [88]. However, silver nanoparticles are more sensitive than gold and detected easily due to its greater extinction coefficient [89].

6. Conclusion

Production of silver NPs have been increased at industrial level because of their unique properties including catalytic activity, electronic properties, optical properties, magnetic property and anti-microbial activity, and proven applicability in diverse areas such as biomedical material, textile fabrics, nano seed, cosmetic, nano fertilizer or nutrition, electronics, sensor, drug delivery, pesticide and water treatment. Onward that, the size, shape and crystal structure is determined based upon the methods what we used so that unique and the major task in the modern synthesis of nanoparticle is choosing of an advanced and ecofriendly method. Even if we can produce structural nanoparticle in such way, physical and chemical method of synthesis of nanoparticles is too expensive and environmentally unsound.

Currently, the discharge of chemical agents from nano fabrics and impurities of impended product are the main challenge in environmental policy and human health care management. Using of expensive tools, hazard chemicals, heavy ray, sputtering radiation, spray pyrolysis techniques and apply high energy demand is not suggested as good as green synthesis of silver nanoparticles. However, there is a better possibility of using green synthesis of silver nanoparticles, such as plant, bacterial and fungal production of nanoparticles is emerging as a novel ecofriendly technique. This is why very important methods since remaining impurity of chemical on silver nanoparticles while synthesis or stabilizing might have not cytotoxic effect along cellular machinery. However, among all, they have their own limitation while the mothed will have been applied in industrial high-level production. Though, plant proteins, alkaloids, flavonoids and amino acid are used as reducing agent, vast vegetation and secondary metabolite culture is subjected whereas careful monitoring of culture broth, optimization and voiding of entire contamination is required in the bacterial biosynthesis of silver nanoparticles, but fungal method is fast and cost effective. The reason is the mycelia of the fungus provide a large surface area to diminish silver nitrate solution into silver nanoparticles through extracellular bioactive enzyme activity. Extracellular metabolites have been extracted outside cell membrane and could reduce silver nanoparticles when fungus stressed in silver ion solution. They have surplus biomass production in a short period of time and ease in down streaming processes which is performed without using toxic chemical agent and excessive thermal energy. In addition to that fungus are better tolerance and metallic bio accumulation properties in which fungal is long lasting fermentation till all substrate go down into the desired products. The silver nanoparticles, which has produced through fungal biosynthesis is free from chemical contamination and be considered safe for medical and agricultural use.

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