Mapana Journal of Sciences
2019, Vol. 18, No. 2, 37-44
ISSN 0975-3303|https://doi.org/10.12723/mjs.49.5

Synthesis of Silver Nano-Particles from Natural Products and its Applications

Anjali Sharma*, Sherin Thomas†, Agnes Mary Mathew‡
and Anil K Agarwal§

Abstract

Infections, that are resistant to the various antibiotics, have increased and become a major concern in the field of drug discovery. This has initiated the need to improve the quality of the existing drugs or find an innovative set of strategies to overcome this issue. In the hope of treating multiple-drug resistant infections, the concept of using natural products to form nanoparticles that could resolve the problem has been introduced. This review talks about the myriad ways of synthesis of silver nanoparticles from natural products which helps in the treatment of multiple diseases.

Keywords: Multiple-Drug Resistant Infections, Natural Products, Silver Nano-Particles

1. Introduction

Nano-biotechnology has proved to be an emerging field in biological sciences and nanotechnology. The research and development in this field of study are growing rapidly and its

* CHRIST (Deemed to be University), Bangalore, India; anjali196sharma@gmail.com
† CHRIST (Deemed to be University), Bangalore, India; sherin.thomas@che.christuniversity.in
‡ CHRIST (Deemed to be University), Bangalore, India; agnes.mathew@che.christuniversity.in)
§ Department of Chemistry, CHRIST (Deemed to be University), Bangalore, India; anilkumar.agarwal@christuniversity.in

major applications lie in the production of new materials in the nanometer scale. These particles have at least one dimension less than 100 nanometers (nm). The reason why they have come into the limelight is because they happen to exhibit better physical and chemical properties than the larger bulk molecules. This distinctive feature arises from the fact that it is in the nanometer scale and has a unique distribution and morphology (as the net particle size goes down, there exists a higher surface area to volume ratio). The metal nanoparticles, in particular, expose an exciting area of study due to some of the interesting properties that it possesses. For example, the specific surface area of the nanoparticle hints at the catalytic and antimicrobial activities; the increase in the specific surface area results in the increase of its biological effectiveness which in turn increases its surface energy [1].

For the synthesis of silver nanoparticles, there are multiple processes that one could use. Some of those are the facile method, thermal decomposition of silver compounds, electrochemical method, sonochemical method, microwave-assisted processes and lately via green chemistry approach. An observation that was made during these synthesis methods was the production of nanoparticles involving an enormous usage of hazardous chemicals. In addition to this, there was negligible material conservation, energy wastage and problematic purification processes. At this juncture, there was an immediate need to develop an environment-friendly process that would help one to produce nanoparticles without the usage of toxic chemicals or wastage of resources, mainly energy.

The biological methods of synthesis of nanoparticles has been proved to be the best method owing to its slower kinetics and better manipulation while controlling the growth of the crystal and consequently, its stabilization [2]. This shot up a trend of research that was dedicated to the synthesis of nanoparticles with the use of plant extracts. This route allowed better control over the size and shape of the crystal, which was thereby used for different nano-technological applications. It also provided the added advantage as this method did not require the elaborate processes like intracellular synthesis and multiple purification steps or the maintenance of microbial cell cultures [1].

The methods employed for the synthesis of silver nanoparticles from various natural products are fairly similar. In most of the cases, the plant extract is treated with an aqueous solution of silver nitrate and then maintained at specific temperatures. For the synthesis of silver nanoparticles from fresh leaves of *Megaphrynium macrostachyum, Corchorus olitorus, Gnetumbucholzianum, Ipomoea batatas* and seed kernels of *Ricinodendron heudelotii*, the organic material was collected and then washed thoroughly under running deionized tap water and the aqueous plant extracts were prepared by boiling 10 g of the cleaned organic material in 200 ml deionized water for 5 min at 80 °C. The extract was filtered through a Whatmann filter and stored at 4 °C. 10 ml of the organic material extract was added to 50 ml of 10 mM aqueous silver nitrate solution and shaken for 1 min, and incubated at room temperature in the dark to minimize the photoactivation of silver nitrate [3]. This process was also employed for the synthesis of silver nanoparticles from *Acalypha indica* and *Curcuma longa*. Here, 1g of mature leaves of *A. indica* was collected along with the rhizome of turmeric. The leaves of *A. indica* were washed, oven dried at 45 °C overnight, then ground into fine powder. Whereas, in the other case, the solid residue of *Curcuma longa* was stored at -20 °C prior to its usage and then ground into fine powder. In both the cases, extraction was done using a Soxhlet apparatus with distilled water or methanol as a solvent for 12 h. Finally, the solvent was concentrated under vacuum using a rotary evaporator. 10 ml of the fresh extract was added to 90 ml of 5 mM aqueous solution of silver nitrate in an incubator in static conditions [4]. For *Catharanthus roseus* and *Camellia sinensis*, the plant extract was prepared by mixing 10 g of the dried, ground leaves with 100 ml of deionized water in 500 ml Erlenmeyer flask. The contents were boiled for 10 min. To 10 ml of this extract, 90 ml of 1 mM of silver nitrate was added and heated for 80 °C for 15 min [1].

2. Discussion

During the generation of the nanoparticles, the organic materials, in the form of plant extracts were cleaned with deionized water to remove all the unwanted dust and other impurities. The various nanoparticles that resulted in a product of these processes were studied by ultraviolet spectroscopy. This is a very important and effective tool to characterize any nanoparticle. This fundamental technique gives an idea of the shape of the crystal and its growth. In most of the cases, the silver nanoparticles begin to form as soon as the plant extract comes into contact with the silver nitrate solution. This results in a sudden change in the colour of the solution suggesting that the nanoparticles have successfully formed.

In the case of *Megaphrynium macrostarchyum* and *Corchorus olitorus*, the colour change was observed by Awwad *et al*. within 2 mins of the reaction. This time was required for the plant extract to reduce ionic silver to the silver nanoparticles. This was the fastest as compared to *Ricinodendron heudelotii* seed kernel extract which took 24 h to reduce. [3] It is interesting to note that most of the plant materials have water soluble components like thiocyanate, nitrate, chlorides and sulphates, starches and tannins, saponins, terpenoids, polypeptides and lectins. In the study of *Acalypha indica* and turmeric extracts (which used a methanol solvent), the silver nanoparticles, formed, showed an inhibition zone of 2.5 cm diameter for *Escherichia coli*. This shows that the nanoparticles were successful in their antimicrobial effect [4]. The resistance of human pathogens to the commercially available antimicrobial agents and antibiotics has posed a need to come up with methods to tackle this problem. Le et al. demonstrated that silver nanoparticles get attached to the cell surface of *Escherichia coli*, post which they penetrated into the cell and destroyed the cell cytoplasm from within, thereby killing the organism. He also found that silver nanoparticles help in increasing the permeability of the cell and thereby make the work simpler [3]. *C. reseus* leaf extract changed the colour of the silver nitrate solution from yellowish-brown to reddish-brown. This indication of the formation of nanoparticles was also validated by the SEM and EDX images that confirmed a cubical shape of the silver nanoparticle having a diameter range of 48-67 nm. This too succeeded in obtaining a maximum zone of inhibition of 11 mm in *Bacillus cereus* and a minimum of 6 mm [1].A similar test was done for an apple extract which also landed at parallel results. The XRD spectrum confirmed a crystalline structure and the UV spectroscopy revealed that the crystals were extra fine and of high homogeneity [5]. An even more interesting result shown by the silver nanoparticle formed from *Agemone mexicana* extract was that it proved to be highly toxic against pathogenic bacteria and fungi at a concentration of 30 ppm along with the usual antibacterial effects of silver nanoparticles. This showed that it obeyed a dual action mechanism of antibacterial activity and membrane-disrupting effect of the polymer subunits [6].

Silver metal has long been recognized for possessing an inhibitory effect on microbes for the medical and industrial processes. The most important application of silver and silver nanoparticles is in the medical industry wherein they are used in topical ointments to prevent infection against burn and open wounds. Aloe vera, an important medicinal plant containing lignin, hemicelluloses, and pectin can be used to produce silver nanoparticles with antimicrobial and antibacterial activity. This was tested by an Agar-Well Diffusion Method. The antibacterial activity of these nanoparticles was studied for the gram-positive *Staphylococcus epidermidis* and gram-negative *Pseudomona aeruginosa* pathogens. It was observed that these particles have a high antibacterial activity when they are processed at 100 °C for 6 hours and 200 °C for 12 hours. The Minimum Inhibitory Concentration (MIC) and Minimal Bactericidal Concentration (MBC) were used to correlate the bactericidal effects of the silver nanoparticles. They were tested for their cytotoxicity using MTT (3-(4,5-dimethyl-2-thiazolyl)-2,5-diphenyltetrazolium bromide) assay. The high activity of the nanoparticles may have arisen from the high concentration of aloe vera incorporated in the silver nanoparticle during the hydrothermal synthesis [11]. Another study of the silver nanoparticles prepared from Harmala Alkaloid showed an increased insecticidal activity against *Trogoderma granarium* (one of the most destructive pests of stored grains and cereal products). Owing to the repeated spraying of chemical pesticides, the insects developed a resistance to the chemicals. This difficulty was overcome by adopting a nano-technological outlook. At sub-lethal concentrations (0.125 – 0.500 mg/mL diet), the normal development of *T. granarium* was disrupted and in addition, the silver nanoparticles were capable of playing a role as an eco-friendly alternative to control all stored grain insects, including *T. granarium* [12].

The boons of silver nanoparticle mainly concentrated around the sphere of antimicrobial and antibacterial activities. But, one event spoke contrary to this: the treatment of activated sludge wastewater. The particles maintain the microbial community diversity in activated sludge. It has been reported that ammonia oxidizing bacteria (AOB) are more vulnerable towards the silver nanoparticle treatment, as compared to the nitrite oxidizing bacteria (NOB) and organic oxidation heterotrophs. Four sequencing batch reactors were operated for over three months with total volume of the reactors 1 L and the effective volume was 700 mL. The self-dispersing silver nanopowder of particle size less than 15 nm was added to the reactor after it reached steady state for over two weeks. The effluent quality thus monitored showed no significant change in the pollutant removal after the addition of the silver nanoparticle in any of the four reactors. COD removal rate was maintained at above 90% and ammonium removal was above 99% in each reactor all the time. It appeared that the nutrient uptake rates in the reactor fed with fresh silver nanoparticle hit a bottleneck when the biomass and silver accumulation increased significantly. It thereby helped to maintain a compositional and functional diversity of the microbial community.

The positive effects caused by silver nanoparticle are therefore non-selective and they can increase the diversity of the microbial community including the population of the pathogens. Therefore, the stimulation of pathogens by silver nanoparticles in the sewage system and wastewater treatment plants can be potentially hazardous owing to the chance of a probable burst of superbugs and their discharge via effluent from wastewater treatment plants [13].

Here, in this report, the various methods of synthesis of silver nanoparticles have been discussed which reduces the silver ions present in the aqueous solution of silver nitrate by the extract of various leaves. Furthermore, they have been employed as an essential tool to fight against different pathogenic bacteria and fungi [7].

3. Conclusion

Nano-materials have been providing solutions for many technological and environmental issues; be it in the field of solar energy conversion, catalysis, medicine, and water treatment. In this review article, we have looked into the synthesis of silver nanoparticles in a simple, cost-effective, and green synthesis approach using various plants extracts. The nanoparticles are also observed to have biological marker properties which can be used in proteins, nucleic acids, hormones, etc. As seen in many cases, they have a high degree of antibacterial and antifungal effects thereby rendering itself useful in the drug formulation of diseases like Cholecystis, Bactremia, Cholangitis, Diarrhea, Urinary Tract Infection, Pneumonia, Mycotoxicosis, etc. [6]. The onset of the production of nanoparticles that possess antimicrobial activities have a wide scope in the target based drug delivery and diagnosis system. The inhibitory action of these nanoparticles have major applications in the field of medicine and the challenge to achieve this goal at par with green chemistry stems from the understanding of the nuclei formation and the interaction of the reacting species in the nuclei morphology.

References

[1] K. S. Mukunthan, E. K. Elumalai, T.N.Patel and V. Ramachandra Murthy, Catharanthus Roseus: A natural source for the synthesis of Silver Nanoparticles, *Asian Pacific Journal,* 2011.

[2] R. Prasad, Synthesis of silver Nanoparticles in Photosynthetic plants, *Journal of Nanoparticles,* 2014.

[3] F. E. Meva, C. E. Ebongue, S. V. F.M.L. Segnou, A. A. Ntoumba, P. B. E. Kedi, R.N. Loudang, A. Y. Wanlao, E. R. Mang and E.A. Mpondo, Natural substances for the synthesis of silver nanoparticles against Escherichia coli- The case of Megaphrynium macrostachyum, Corchorus olitorus, Ricinodendron heudelotii, Gnetum bucholzianum and Ipomoea batatas, *Journal of Nanoparticles,* 2017.

[4] P. Manonmani, N. Geetha, J. Jerlin Sowmiya, M. Ramar, R. R. Erusan and R. Mariselvam, Synthesis of silver nanoparticles using natural products from Acalypha Indica (Kuppaimeni) and Curcuma Longa (Turmeric) on antimicrobial activities, *International Journal of Pharmaceutical Research and Bio-sciences,* 2015.

[5] Z. A. Ali, R. Puteh, R. Yahya and S. D. Sekaran, Green synthesis of silver nanoparticles using apple extracts and its antimicrobial properties, *Advances in Material Sciences and Engineering,* 2016.

[6] A. Singh, D. Jain, M. K. Upadhay, N. Khandelwal and H. N. Verma, Green synthesis of silver nanoparticles using Argemone Mexicana leaf extract and evaluation of their antimicrobial activities, *Journal of Nanomaterials and Biostructures,* 2010.

[7] A. A. Haleemkhan, B. Vidya Vardhini and Naseem, Synthesis of nanoparticles from plant extracts, *International Journal of Modern Chemistry and Applied Sciences,* 2015.

[8] M. Jayandran, M. Muhammed Haneefa and V. Balasubramanaian, Green synthesis and characterization of Manganese nanoparticles using natural plant extracts and evaluation of its antimicrobial properties, *Journal of Applied Pharmaceutical Science,* 2015.

[9] D. Jain, S. L. Kothari, S. Kachhwaha and H. Kumar Daima, Synthesis of plant mediated silver nanoparticles using papaya fruit extract and evaluation of their antimicrobial activities, *Journal of Nanomaterials and Biostructures,* 2009.

[10] S. Iravani, Green synthesis of metal nanoparticles using plants, *The Journal of Royal Society of Chemistry,* 2011.

[11] S. Prathap Chandran, M. Chaudhary, R. Pasricha, A. Ahmad and M. Sastry, Synthesis of Gold nanotriangles and silver nanoparticles using Aloevera plant extract, *Biotechnology Progress,* 2006.

[12] A. Abdulrhman, G. E. Nenaah and D. M. Shawer, Facile synthesis of silver nanoparticles using harmala alkaloids and their insecticidal and growth inhibitory activities against the Khapra Beetle, *Journal of Pest Science,* 2017.

[13] Z. Shneg, J. D. V. Nostrand, J. Zhou and Y. Liu, Contradictory effects of silver nanoparticles on activated sludge wastewater treatment, *Journal of Hazardous Materials,* 2017.