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Mycofabricated Silver Nanoparticles: An Overview of Biological Organisms Responsible for its Synthesis

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Abstract

Silver nanoparticles are the most mentioned nanoparticles with increased production and commercialization along with widespread applications. Several studies revealed that the synthesis of nanoparticle of silver can be accomplished by employing numerous biological organisms such as plants, fungi, bacteria etc. to produce silver nanoparticles of enhanced properties.

Keywords: Fungi; Silver nanoparticles; Bacteria

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Introduction

Silver nanoparticles

Among different nanoparticles, Nanoparticles of silver is the most mentioned nanoparticle with increased production and commercialization along with widespread applications. A number of examples revealed that amalgamation of silver nanoparticles could be accomplished by using biological organisms. Extracellular synthesis of stable silver nano crystals has been documented in fungus *Aspergillus flavus* [1]. Similarly, endophytic fungi *Epicoccum nigrum* was found to synthesize Silver nanoparticles at different pH and temperature [2]. Similarly bacterias like *Bacillus* species and *Brevibacterium casei* are well known silver nanoparticle producers [3,4]. In addition spherical shaped silver nanoparticles of size 10-25 nm was reported to be synthesize by Curry leaf (*Murraya koenigii*) etc [5].

Synthetic approaches of silver nanoparticle synthesis

Presently there are quite a lot of methods employed in the fabrication of silver nanoparticles. But these approaches involve the applications of reducing agents like hydrazine [6], sodium borohydride [7], thiourea [8], thiophenol [9], mercaptoacetate [10] etc., which are hazardous and damaging to the environment. Such reducing agents make the synthesis process costly. Consequently biological synthesis of silver nanoparticle is now the most eco- friendly and cost effective process.

Biosynthesis of silver nanoparticle

Bio fabrication of silver nanoparticles could be accomplished by employing different types of biological organisms such as bacteria, plants and fungi.

Bacteria in silver nanoparticle synthesis

Silver nanoparticles have been produced by different bacteria as enlisted in **Table 1.** Production of uniformly distributed Silver nanoparticles of size 50nm was reported in *Escherichia coli* [11,12]. Furthermore by varying the physiochemical factors such as pH, temperature, substrate concentration and incubation time, size of silver nanoparticle could be controlled [11]. On the other hand extremophilic *Ureibacillus thermosphaericus* was explored to have potential to produce silver nanoparticle at raised temperatures and increased silver ion concentrations. Using a concentration of 0.01 M AgNO3 at 800°C temperature maximum yield of Silver nanoparticles could be achieved [13]. *Bacillus cereus* [14], *Bacillus thuringiensis* [15] and *Corynebacterium* strain SH09 [16] have also been reported to produce Silver nanoparticles. In another reported study, *Pediococcus pentosaceus, Lactococcus garvieae* and *Enterococcus faecium*, were used to produce Silver nanoparticles non-enzymatically through the interaction of organic compounds present on the surface of the bacterial cell with silver ions. *Lactobacillus spp* depicts rapid synthesis of Silver nanoparticles for better silver nanoparticle recovery at high pH [17-31] etc.

Plants in silver nanoparticle synthesis

Names of well-known plants are enlisted in **(Table 2)** which is recognized as silver nanoparticle producers. Formation of silver nanoparticles at high temperature of 95°C was reported in *Cardiospermum helicacabum* leaf extracts [33]. Similarly rate of bioreduction is directly proportional to the broth concentration while studying the production of silver nanoparticle in Curry leaf (*Murraya koenigii*) extract [34]. Thus reaction kinetics and morphology of nanoparticles is affected by precursor solution (silver nitrate) and reductant (plant extract) concentration [35] as depicted during the formation of silver nanoparticle from an aqueous extract of *Pulicaria glutinosa*. Silver nanoparticles synthesis from *clove* extract [35] and *Aloe vera* plant extract [36] have also been reported. Myco-nanotechnology is the fabrication of metallic nanoparticles by employing fungi. This technology combines nanotechnology with mycology with extensive potential, mainly due to widespread occurrence and diversity of fungi [37-45]. Names of well-known fungal species have been enlisted in **Table 3** which is currently recognized as silver nanoparticle producers [46-59].

Conclusion

Thus we can conclude that biological organisms such as Fungi, Bacteria, and plants could be employed as suitable nano-factories for the biological synthesis of nanoparticles of silver.

Table 2. List of plants synthesizing silver nanoparticle of various size.

S.no	Organism	Size(nm)
1	*Azadirachta indica*	50 [36]
2	*Carica papaya*	60–80 [37]
3	*Cinnamomum camphora leaf*	55–80 [38]
4	*Cinnamomum camphora Leaf*	5–40 [39]
5	*Coriandrum sativum leaf extract*	26 [40]
6	*Gliricidia sepium*	10–50 [41]
7	*Glycine max (soybean) leaf extract*	25–100 [42]
8	*Jatropha curcas*	10–20 [43]
9	*Phyllanthus amarus*	18–38 [44]

Table 1. List of bacteria synthesizing silver nanoparticle of various size.

S.no	Organism	Size (nm)
1	*Bacillus cereus*	4 and 5 [18]
2	*Bacillus licheniformis*	50 [19,20]
3	*Bacillus megaterium*	46.9 [21]
4	*Bacillus sp.*	5–15 [22]
5	*Bacillus subtilis*	5–60 [23]
6	*Brevibacterium casei*	50 [20]
7	*Corynebacterium sp.*	10–15 [16]
8	*Escherichia coli*	1–100 [24]
9	*Geobacter sulfurreducens*	200 [25]
10	*Klebsiella pneumonia (culture supernatant)*	50 [26]
11	*Lactic acid bacteria*	11.2 [27]
12	*Lactobacillus Strains*	500 [28]
13	*Morganella sp.*	20 [29]
14	*Proteus mirabilis*	10–20 [29]
15	*Pseudomonas stutzeri AG259*	200 [30]
16	*Staphylococcus aureus*	1–100 [31]

Table 3. List of fungi synthesizing silver nanoparticles.

S.no	Microorganism	Size (nm)
1	*Aspergillus clavatus*	10-25 [45]
2	*Aspergillus flavus*	1.61-8.92 [46]
3	*Aspergillus fumigatus*	5-25 [47]
4	*Aspergillus niger*	20 [48]
5	*Cladosporium cladosporioides*	10-100 [49]
6	*Fusarium acuminatum*	5-40 [50]
7	*Fusarium oxysporum*	5-50 [51]
8	*Fusarium semitectum*	10-60 [52]
9	*Fusarium solani*	5-35 [53]
10	*Penicillium brevicompactum WA 2315*	23-105 [54]
11	*Penicillium fellutanum*	1-100 [55]
12	*Phanerochaete chrysosporium*	100 [47]
13	*Trichoderma asperellum*	13-18 [56]
14	*Trichoderma viride*	5-40 [57]
15	*Verticillium sp.*	12-25 [58]
16	Yeast strain *MKY3*	2-5 nm [59]

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