Review Article: Green Synthesis of Silver Nanoparticles and Their Application

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Received:- 03 July 2021/ Revised:- 12 July 2021/ Accepted:- 24 July 2021/ Published: 31-07-2021

***Abstract*—** *Nanoparticles are small particles which ranges from 1-100nm in size. Nanoparticles can be synthesized through physical, chemical and biological method. Synthesis of nanoparticles through biological method which also known as green synthesis is eco-friendly and non-expensive method. This review gives idea about how silver nanoparticles are produce by using microorganisms and plant extract and their mechanism for biosynthesis. This review also shows an insight on wide application of silver nanoparticles in various fields.*

Keywords*— *Nanobiotechnology, silver nanoparticles, green synthesis, microorganisms.

I. INTRODUCTION

Nanotechnology is important science field which deals with production, manipulation and use of material ranging in nanometers. ”Nano” is derived from the Greek word “nanos” meaning dwarf, tiny or very small (Rai et al., 2008). Nanotechnology has emerged as a dynamically developing area of scientific interest within the world. Nanoparticles are defined as a nanoscale particle of size within 1 to 100 nm. In nanotechnology, a particle is defined as is a small object that behaves as a whole unit respect to its transport and properties. Nanoparticles had a wide variety of application in the major fields of medicine, therapeutics, and diagnostic agents (Colvin et al., 1994, Wang and Herron, 1991, Schmid.G, 1992, Hoffman et al., 1992, Hamilton and Baetzold, 1979, Mansur et al., 1995, Senapati.S, 2005).

Different types of nanomaterials like copper, zinc, titanium, magnesium, gold, alginate & silver have come up but silver nanoparticles have proved to be most effective against bacteria, viruses & other eukaryotic microorganisms. Biologically synthesized silver nanoparticles (SNPs) are being widely used. Nanoparticles have been widely used for disinfection of water and to remove arsenic from water. Ag nanomaterials also have many other applications in various fields, such as nanoscale detection and solar cells.

Generally there are two approaches which are involved in the syntheses of silver nanoparticles, either from ‘‘top to bottom’’ approach or a ‘‘bottom to up’’ approach as depicted in Fig.1 (Ahmed et al., 2010). In bottom to up approach, nanoparticles can be synthesized using chemical and biological methods by self-assemble of atoms to new nuclei which grow into a particle of nanoscale. In bottom to up approach, chemical reduction is the commonest scheme for synthesis of silver nanoparticles (Elghanian et al., 1997; Hurst et al., 2006).

Different organic and inorganic reducing agents, like sodium borohydride ($NaBH_4$), sodium citrate, ascorbate, elemental hydrogen, Tollen’s reagent and N, N-dimethyl formamide (DMF) are used for reduction of silver ions (Ag^+) in aqueous or non-aqueous solutions (Tran et al., 2013; Iravani et al., 2014).In case of top to bottom approach; nanoparticles are generally synthesized by evaporation–condensation method. Also in top to bottom approach, suitable bulk material break down into fine particles by size reduction with various lithographic techniques e.g. grinding, milling, sputtering and thermal/laser ablation (Elghanian et al., 1997; Hurst et al., 2006).

The use of green materials like plant extracts, microbial extracts, algal extracts and fungal extracts are used for synthesis of Silver nanoparticles as described in Fig 2.Various reducing agents present in the green extracts are responsible for synthesis of Silver nanoparticles (Roy et al., 2019).

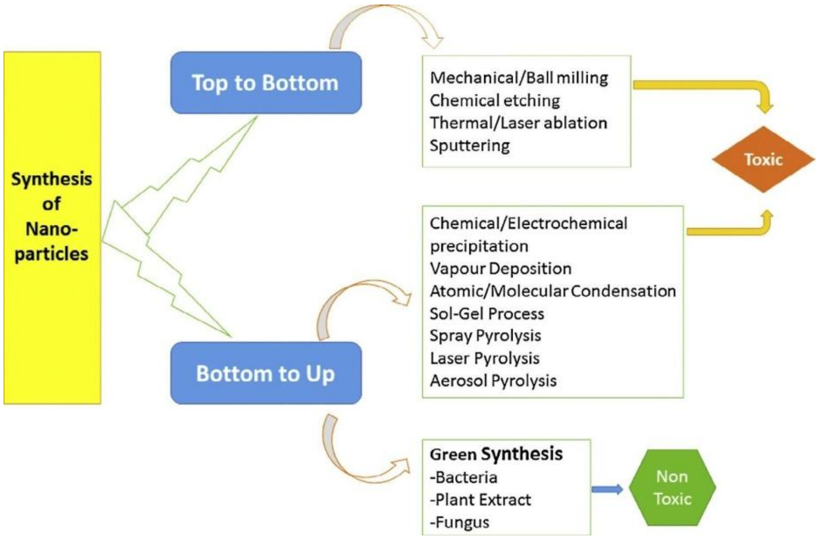

FIGURE 1: Different approaches of synthesis of silver nanoparticles (Ahmed et al., 2010).

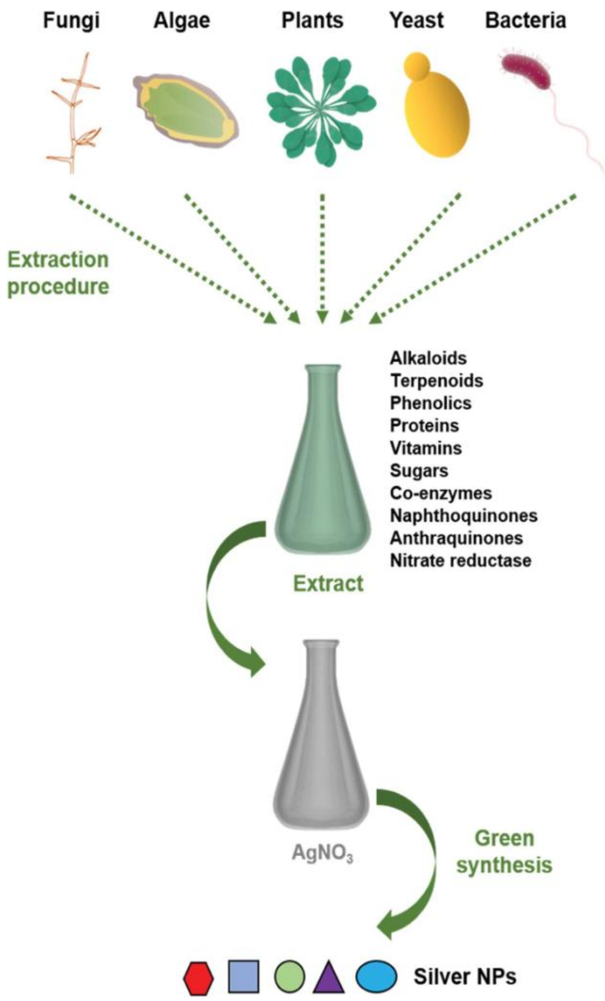

FIGURE 2: Schematic representation of the procedure for green synthesis of silver nanoparticles using various biological entities (Roy et al., 2019).

The biological method is also referred as green synthesis method. The biological method includes microorganisms like bacteria, fungi, algae, yeast and viruses and also plant extracts. Microorganisms and plants play role in absorption and accumulation of inorganic metallic ions from their surrounding (Shah et al., 2015). They secrete different enzymes in large quantities which have ability to hydrolyze metals and bring reduction of metals ions (Chokriwal et al., 2014).

It is found that the reduction rate of metal ion using biological method is quicker compared to physical and chemical method. The synthesis or production of silver nanoparticles by using biological means is not much expensive as compared to physical and chemical method. It is necessary to develop an environmental and economically friendly method for production of nanoparticle without involving any toxic chemicals, (Iravani S, 2014).

II. GREEN SYNTHESIS OF SILVER NANOPARTICLE BY USING PLANT EXTRACT

Plant extracts used for the synthesis of metal nanoparticles. Indeed, the use of plant for the assembly of silver nanoparticles has received many attentions because of its rapid, nonpathogenic, economical protocol and providing one step technique for the green synthesis processes (Huang et al., 2007).

Recently many researchers reported that AgNPs have been synthesized using various plants such as *Acalypha indica* (krishnaraj et al., 2010), *Aloe Vera* plant extract (Chandran et al., 2006), *Emblica officinalis* (Latha et al., 2015), leaves extract of *Citrus limon* (Mohapatra et al., 2015), *tea* (Nabikhan et al., 2010), etc. Comprehensive list of plants utilized for synthesis of Silver nanoparticles is given in Table 1.

TABLE 1
GREEN SYNTHESIS OF SILVER NANOPARTICLES BY USING DIFFERENT PLANT EXTRACT

Sr.No.	Plants	Size (nm)	Plant part	Reference
1	*Ficus carica*	13	Leaves	Geetha N et al. (2014)
2	*Moringa oleifera*	57	Leaves	Prasad and Elumalai. (2011)
3	*Acalypha indica*	20-30	Leaves	Krishnaraj et al. (2010)
4	*Carica papaya*	25-50	Leaves	Jain D et al. (2009)
5	*Datura metel*	16-40	Leaves	Kesharwani J et al. (2009)
6	*Aloe vera*	50-350	Leaves	Chandran SP et al. (2006)
7	*Tea*	20-90	Leaves	Nabikhan A et al. (2010)
8	*Eucalyptus hybrid*	50-150	Peel	Dubey M et al. (2009)
9	*Acorus calamus*	31.83	Rhizomes	Nakkala JR et al. (2014)
10	*Saraca indica*	20	Leaves	Perugu S et al. (2015)
11	*Azadirachta indica*	20	Leaves	Banerjee P et al. (2014)
12	*Cucurbita maxima*	19	Petals	Nayak D et al. (2015)
13	*Emblica officinalis*	25.4	Leaves	Latha M et al. (2015)
14	*Annona muricata*	20-53	Leaves	Santhosh SB et al. (2015)
15	*Citrus limon*	10-30	Peel	Mohapatra et al. (2015)
16	*Ocimum sanctum*	4-30	Leaves	Singhal et al. (2011)
17	*Allium cepa*	33.6	Leaves	Saxena et al. (2010)
18	*Bryophyllum*	18-21	Leaves	Saikia et al. (2015)
19	*Capsicum annum*	30-70	Leaves	Li et al. (2007)
20	*Euphorbia hirta*	40-50	Leaves	Elumalai et al. (2010)
21	*Lantana camara*	12.55	Leaves	Sivakumar et a. (2012)
22	*Mentha piperita*	90	Leaves	Ali et al. (2012)
23	*Citrullus colocynthis*	31	Leaves	Satyavani et al. (2007)
24	*Centella asiatica*	-	Leaves	Palaniselvam et al. (2011)
25	*Morinda tinctoria*	79-96	-	Vanaja et al. (2014)
26	*Morinda pubescens*	25-50	Leaves	Mary and Inbathamizh (2014)
27.	*Morinda citrifolia*	30-55	Root	Suman et al. (2013)
28.	*Aerva lanata*	18.62	Leaves	Joseph et al. (2014)
29.	*Zizipus jujube*	20-30	Leaves	Gavade et al. (2015)
30.	*Nelumbo nucifera*	16.7	Root	Sreekanth et al. (2014)
31.	*Prosopis farcta*	10.8	Leaves	Miri et al. (2015)
32.	*Cocos nucifera*	22	Coir	Roopan et al. (2013)
33.	*Lansium domesticum*	10-30	Fruit	Shankar et al. (2014)
34.	*Rosmarinus officinalis*	10-33	Leaves	Ghaedi et al. (2015)
35.	*Skimmia laureola*	46	Leaves	Ahmed et al. (2014)
36.	*Tephrosia tinctoria*	73	Stem	Rajaram et al. (2015)
37.	*Quercus branti*	6	Leaves	Korbekandi et al. (2015)
38.	*Justica adhatoda*	5-50	Leaves	Bose and Chatterjee, (2015)

The common protocol for synthesis of silver nanoparticle by using plant extract is carried out as described in Fig.3 (S. Rajeshkumar, L.V. Bharath, 2017).

2.1 General method for biosynthesis of silver nanoparticles by using plant extract

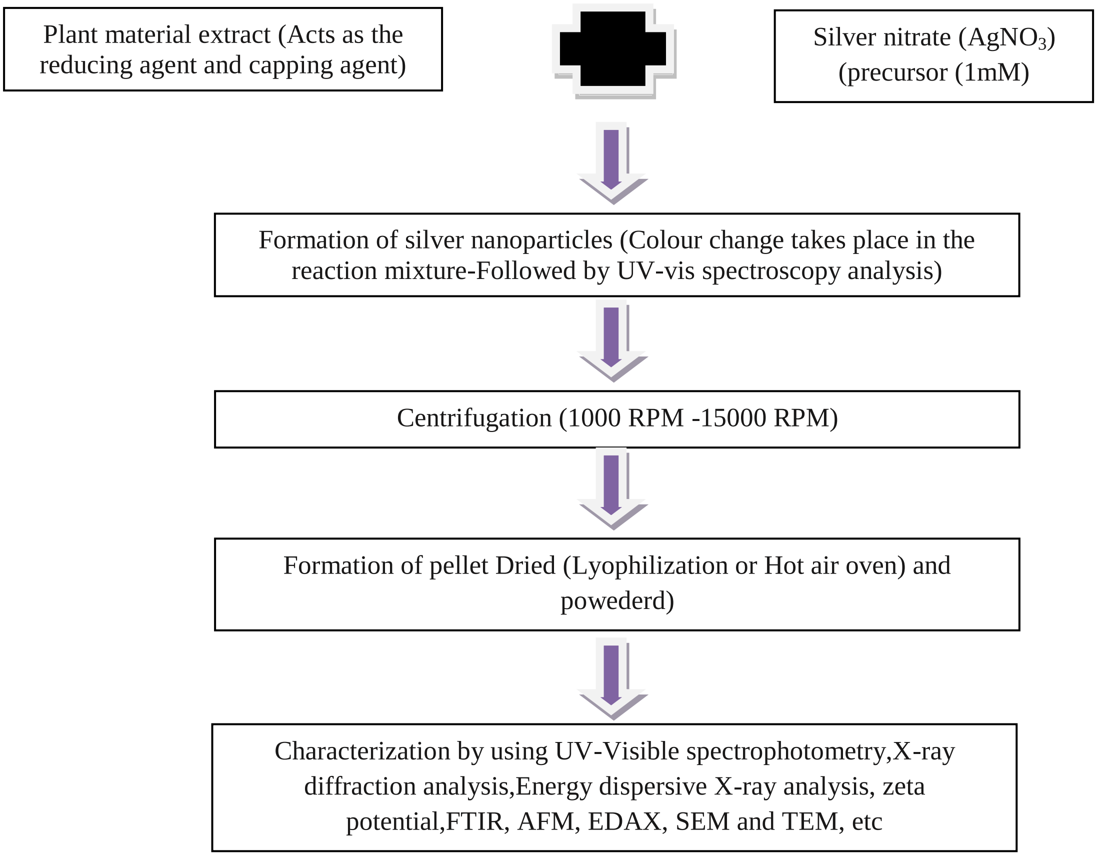

FIGURE 3: Biosynthesis of silver nanoparticle by using plant extract (S. Rajeshkumar, L.V. Bharath, 2017)

2.2 Mechanism of synthesis of silver nanoparticle using plant extract:

The parts of plants like as bark, stem, root, fruit, peel, seed, callus, leaves and flower are used for the synthesis of Silver nanoparticles (Singh et al., 2016). Plant extracts contain secondary metabolites like phenolic acid, flavonoids, alkaloids, amino acid, proteins, vitamins, enzymes, polysaccharide and terpenoids. They are liable for reduction of silver salts (Ag+) into silver ions (Ag°) (Kulkarni and Muddapur, 2014). Water soluble phytochemicals including organic acids, quinones and flavones are liable for the reduction of the silver ions within the reaction mixture (Doughari J.H, 2009).

Singhal et al. described biosynthesis and antimicrobial activity of silver nanoparticles using *Ocimum sanctum* extract. They showed that leaf extract can reduce silver ions into silver nanoparticles within 8 min of response time. The sizes of biosynthesized silver nanoparticles were within range of 4–30 nm and possessed antimicrobial activity. They showed silver nanoparticles were exhibited more antimicrobial activity on Gram-negative bacteria than Gram-positive. Also reported that synthesized silver nanoparticles have stronger activity than silver nitrate and standard antibiotic ciprofloxacin (Singhal et al., 2011).

Mohapatra et al. reported *Citrus limon* extract mediated synthesis of silver nanoparticles. The biosynthesized silver nanoparticles are of in the size range of 10-30 nm. They showed that addition of NaOH may be a key factor for rapid biosynthesis of stable aqueous dispersions of high concentration of silver nanoparticles. So, the alkaline environment is favourable for the biosynthesis of silver nanoparticles using *Citrus limon* (Mohapatra et al., 2015).

Silver nanoparticles were synthesized on reduction of silver nitrate solution by aqueous extract of *Azadirachta indica* leaves by Prathna et al. and the growth kinetics of silver nanoparticles was investigated having size of 10–35 nm.Colloidal silver nanoparticles were synthesized by a simple green method using thermal treatment of aqueous solutions of silver nitrate and natural rubber latex extracted from Hevea brasilensis. The silver nanoparticles presented diameter starting from 2 nm to 10 nm and had spherical shape with face centred cubic (fcc) crystalline structure (Prathna et al., 2011).

Sarkar et al. reported synthesis of silver nanoparticles of varying sizes using parthenium leaf extract at a higher temperature of 100 °C as well as at room temperature. They showed the variation of particle size with the reaction temperature and reaction time. The synthesized colloidal silver nanoparticles were photo-luminescent. The size of the silver nanoparticles synthesized after 2 minutes of chemical reaction at a higher temperature of 100 °C lie within 40-160 nm and the average size of the nanoparticles was ~ 110 nm (Sarkar et al., 2010).

III. GREEN SYNTHESIS OF SILVER NANOPARTICLES BY USING BACTERIA

The first bacteria which was found to be synthesizing silver nanoparticles was *Pseudomonas stutzeri AG259* Strain isolated from silver mine (Haefeli et al, 1984). Selected examples bacteria involve in the synthesis of Silver nanoparticles are given in Table 2. The most common site for biosynthesis of nanoparticles is cellular entities and their membrane (Mandal et al., 2006).

TABLE 2
GREEN SYNTHESIS OF SILVER NANOPARTICLES BY USING DIFFERENT BACTERIA

Sr No.	Bacteria	Types of nanoparticles	Size (nm)	Location/Morphology	Intracellular or Extracellular	Reference
1	*Pseudomonas stutzeri AG259*	Ag, Ag_2S	<200	Periplasmic space	Intracellular	Klaus et al (1999)
2	*Bacillus cereus*	Ag	20-40	Spherical	-	Sunkar et al (2012)
3	*Bacillus subtilis*	Ag	5-50	Spherical and triangular	-	Saifuddin et al (2009)
4	*Corneybacterium sp. SH09*	Ag	10-15	-	-	Zhang et al (2005)
5	*Klebsiella pneumonia*	Ag	5-32	-	Extracellular	Shhverdi et al (2007)
6	*Escherichia coli*	Ag	8-9	Spherical	-	Manhantry et al (2013)
7	*Escherichia coli DH5 alpha*	Ag	10-100	Spherical	-	H.R Ghorbani et al (2013)
8	*Plectonema boryanum (Corneybacterium)*	Ag	1-10	-	Intracellular	Lengke (2006)
9	*Serratia nematodiphila*	Ag	10-31	Spherical and crystalline	-	Malarkodi et al (2013)
10	*Pseudomonas putida NCIM 2650*	Ag	~70	Spherical	-	Rajasree et al (2012)
11	*Acetobacter Xylinum*	Ag	-	Cellulose fibre	-	Braud et al (2008)
12	*Bacillus megaterium*	Ag, Pb, Cd	10-20	-	-	Prakash et al (2010)
13	*Nacardiopsis sp. MBRC-1*	Ag	~45	Spherical	-	Manivasagan et al (2013)
14	*Idiomarina sp PR58-8*	Ag	26	-	-	Seshadri et al (2012)
15	*Lactobacillus strains*	Ag-Au alloys	100-300	Crystalline and cluster	-	Nair & T.Pradeep et al (2002)
16	*Acinetobacter calcoaceticus*	Ag	8-12	Spherical	Extracellular	Sing et al (2013)
17	*Caluconobacterium*	Ag	10	-	Extracellular	Krishnaraj and Berchmans (2013)
18	*Pedicoccus pentos aceus*	Ag			Intracellular	Sintubin et al (2009)

The general method used for biosynthesis of silver nanoparticles is depicted in Fig. 4. (Chokriwal et al., 2014):

3.1 General method for biosynthesis of silver nanoparticles by using bacteria

Isolation of specific microbial strain and culturing it in specific nutrient media.

⇩

Addition of corresponding metal salt ($AgNO_3$) into the medium from which nanoparticles are required.

⇩

Allowing chelating redox reaction at specific pH and temperature

⇩

The change in color represents the presence of nanoparticle formation which are further verified with the help of UV visible spectrum.

⇩

Nanoparticle extraction and characterization by using DLS, XRD, TEM, etc.

⇩

Application of separated nanoparticles in various fields.

FIGURE: The genera methodology for biosynthesis of silver nanoparticles by using bacteria

3.2 Mechanism / synthesis of sliver nanoparticles

Various mechanisms of synthesis of AgNps are described as a part of microbial resistance for cellular detoxification. This involves changes in solubility of inorganic ions with the help of enzymatic reduction and or precipitation of soluble toxic substance to insoluble non toxic nano structure. The oxidoreductase enzymes for e.g – NADH – dependent nitrate reductase, cystine desulfhydrase etc and cellular transporters are involved in extracellular and intracellular synthesis of nanoparticles (Golmohmmadi et al., 2017).Mechanism which are considered includes bio-absorption, bio accumulation, extra ellular complexion, reduction or oxidation etc. (Beveridge et al., 1997).

IV. GREEN SYNTHESIS OF SILVER NANOPARTICLES BY USING FUNGI

Fungi have several excellences for synthesis of different types of nanoparticles over other organisms due to the presence of enzymes, proteins and reducing components on their cell surfaces (Narayanan and Sakthivel, 2011). Fungi even have better tolerance and possess higher metal-bioaccumulation property, which is liable for the high accumulation of silver nanoparticles (Singh et al., 2016; Alghuthaymi et al., 2015; Castro-Longoria et al., 2011)., and therefore the synthesized particles also tend to be smaller in size (Mukherjee et al., 2002; Volesky and Holan, 1995).

The first synthesis of fugus-mediated nanoparticles was reported in the beginning of the 20^{th} century and silver nanoparticles synthesized by using fungus *Verticillium* (Mukherjee et al., 2001). The synthesis mechanism is based on the reduction of the Ag+ ions by the nitrate reductase present in the fungal system (Mohanpuria et al., 2008). Biosynthesis of silver nanoparticles from pathogenic and non-pathogenic fungi has been investigated extensively. (Siddiqi and Husen, 2016, Duran et al., 2005, Ingle et al., 2008, Ingle et al., 2009, Kathiresan et al., 2009).

Synthesis of silver nanoparticles mediated by fungi can be carried out by using either spores suspension, mycelia or cell free supernatant (Liu et al., 2018 and Zomorodian et al., 2016).The nanoparticles are formed on the surface of the mycelia but not in the solution. Ag+ ions are adsorbed on the surface of the fungal cells because of electrostatic interaction between negatively charged carboxylate groups in enzymes present within the cell membrane of mycelia and positively charged Ag ions. Finally, the silver ions are reduced by the enzymes present in cell wall, leading to the formation of silver nuclei (Mukherjee et al., 2001).

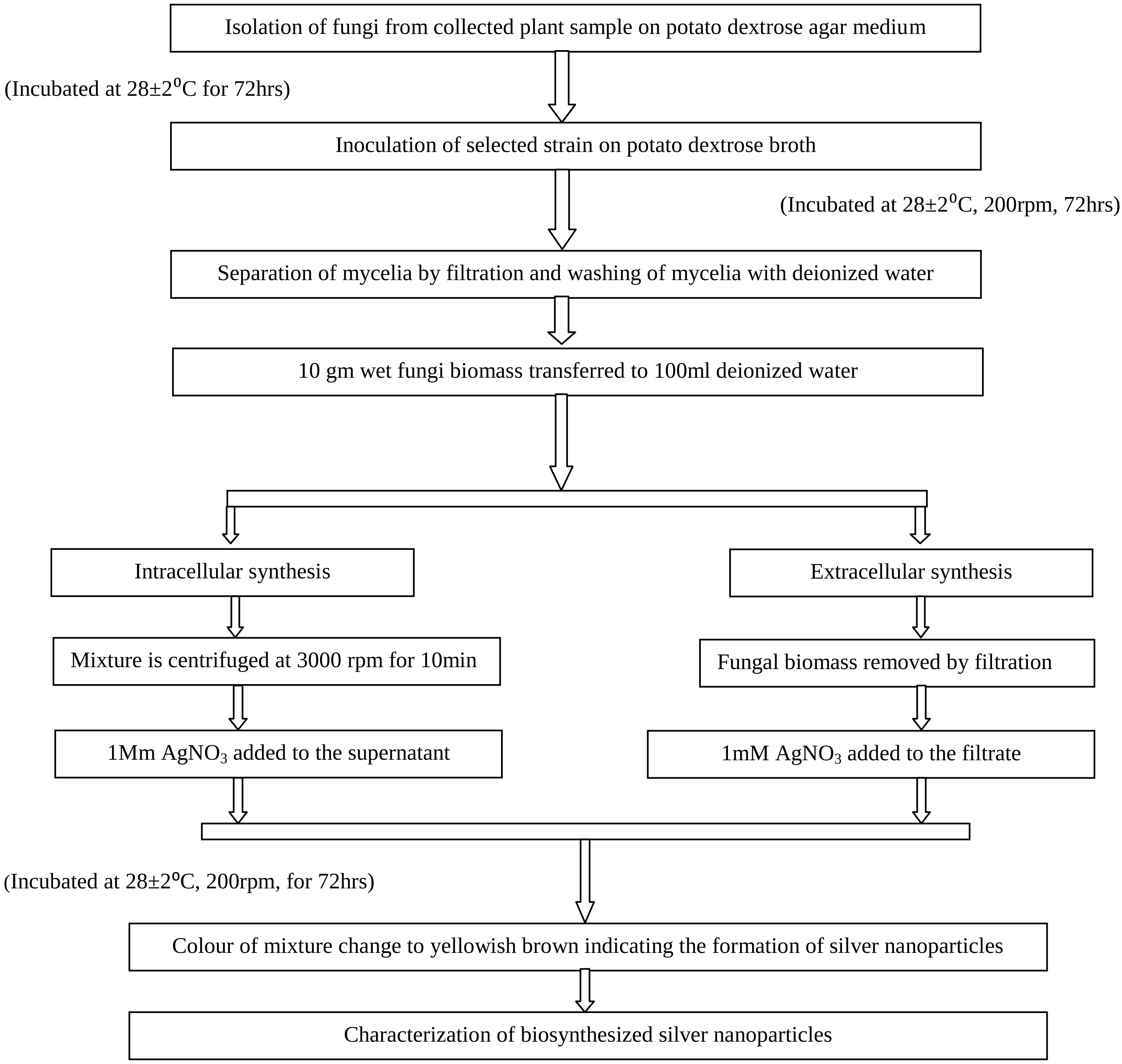

FIGURE 5. General methodology for biosynthesis of silver nanoparticles by using fungi (Shukla and Sandhu, 2017).

4.1 General method for biosynthesis of silver nanoparticles by using fungi.

Fig.5 depicts the general methodology for biosynthesis of silver nanoparticles by using fungi (Shukla and Sandhu, 2017). The synthesis of silver nanoparticles mediated by fungi can occur at both intracellular and extracellular locations (Siddiqi et al., 2018).In intracellular synthesis, the metal precursor is added to the mycelial culture and is internalized within the biomass. Extraction of the nanoparticles is required after the synthesis, centrifugation, chemical treatment, and filtration are used to disrupt the biomass and release the nanoparticles (Castro-Longoria et al., 2011; Rajput et al., 2016; Molnár et al., 2018).

In extracellular synthesis, the metal precursor is added to the aqueous filtrate containing fungal biomolecules, resulting in the formation of free nanoparticles in the dispersion. (Azmath et al., 2016; Sabri et al., 2016; Gudikandula et al., 2017; Costa Silva et al., 2017).

Fungi involved in the synthesis of Silver nanoparticles are listed in Table 3.

TABLE 3
GREEN SYNTHESIS OF SILVER NANOPARTICLES BY USING DIFFERENT FUNGI

Sr.no	Species	Size (nm)	References
1	*Fusarium semitectum*	20-25	Basavaraja et al., 2008
2	*Nemania sp.*	33.52	Bao and Lan, 2018
3	*Trichoderma harzianum*	50.10	Ahluwalia et al., 2014
4	*Macrophomina phaseolina*	5-40	Chawdhury et al., 2014
5	*Cladosporium cladosporioides*	10-100	Balaji et al., 2009
6	*Cariolus versicolor*	25-75	Sanghi and Verma, 2009
7	*Aspergillus fumigates*	5-25	Bhainsa and D'Souza, 2006
8	*Verticillium*	21-25	Mukherjee et al., 2001
9	*Penicillium fellutanum*	5-25	Kathiresan et al., 2009
10	*Aspergillus terreus*	1-20	Li et al., 2012
11	*Duddingtonia flagans*	30-409	Costa silva et al., 2017
12	*Epicoccum nigrum*	1-22	Qian et al., 2013
13	*Ganoderma sessiliforme*	~45	Mohanta et al., 2018
14	*Aspergillus fumigates*	5-25	Ratnasri and Hemalatha, 2014
15	*Rhodotorula mucilaginosa*	13.70	Farsi and Farokhi, 2018
16	*Rhizopus stolonifer*	2.86	Abdel Rahim et al., 2017
17	*Rhizoctonia salani*	2-22	Ashrafi et al., 2013
18	*Trichoderma reesei*	5-50	Vahabi et al., 2011
19	*Trichoderma viride*	5-40	Fayaz et al., 2010
20	*Fusarium oxysporum*	8-14	Senapati at al., 2005
21	*Penicillium brecompactum*	23-105	Shaligram et al., 2009
22	*Trichoderma asperellum*	13-18	Mukherjee et al., 2008
23	*Isaria fumosorosea*	51.31-111.02	Banu and Balasubramanian, 2014a
24	*Penicillium polonicum*	10-15	Neethu et al., 2018
25	*Rhodotorula glutinis*	15.45	Cunha et al., 2018
26	*Guignordia mangifera*	5-30	Balakumaran et al., 2015
27	*Arthroderma fulvum*	20.56	Xue et al., 2016
28	*Aspergillus flavus*	1-8	Vigneshwaran et al., 2006
29	*Trichoderma longibrachiatum*	10	Elamowi et al., 2018
30	*Aspergillus niger*	20	Gade et al., 2008
31	*Alternata alternate*	20-60	Gajbhiye et al., 2009
32	*Phoma glomerata*	60-80	Birla et al., 2009
33	*Phanerochaete chrysosporium*	50-200	Vigneshwaran et al., 2007
34	*Fusarium solani*	5-35	Ingle et al., 2009
35	*Rhizopus nigricans*	35-40	Ravindra and Rajasab., 2014

4.2 Mechanism of synthesis of silver nanoparticles

Silver ions are trapped at the surface of the fungal cells where they undergo succeeding reduction by the enzymes like naphthoquinones and anthraquinones present within the fungal system. (Mohanpuria et al., 2008).Further reduction by the NADPH-dependent nitrate reductase and a shuttle quinone extracellular process are liable for nanoparticle formation and its stabilization (Mukherjee et al., 2001).A significant disadvantage of the microbes to synthesize silver nanoparticles is that it is an extremely slow technique once compared with plant extracts (Tashi et al., 2016). Naphthoquinones and anthraquinones are extracellular enzyme present into fungal cell wall said to acceleratereduction (Ahmed et al., 2003)

Clasdosporium cladosporioides is used to synthesize silver nanoparticles.In this method the release of organic acids, protiens and polysaccharides are responsible for formation of spherical crystalline silver nanoparticles (Balaji et al., 2009).The genus *Fusarium* can synthesize metal nanoparticles intracellularly and extracellularly. The proposed hypothetical mechanisms for synthesis of silver nanoparticles is that NADH-dependent nitrate reductase enzyme secreted by *Fusarium oxysporum* is liablefor the reduction of aqueous silver intosilver nanoparticles (Ahmad et al., 2003).

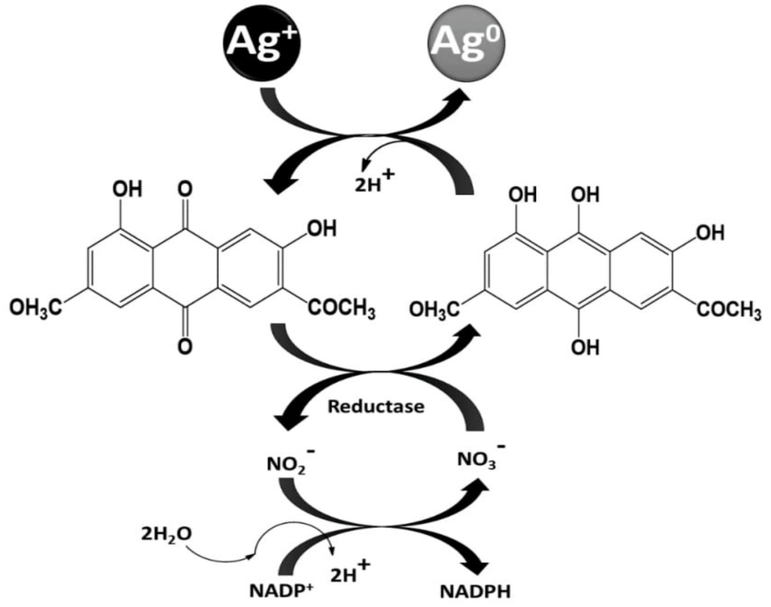

FIGURE 6: Hypothetical mechanism of AgNPs biosynthesis from *Fusarium oxysporum* (Srivastava et al., 2019).

The role of anthraquinone and therefore the NADPH-nitrate reductase within the biosynthesis of silver nanoparticles, also it had been hypothesized that the electron required to satisfy the deficiency of aqueous silver ionsand converted into Ag neutral (Ag0 i.e., AgNPs) was demonstrated by quinone and NADPH (Fig.6) (Srivastava et al., 2019).

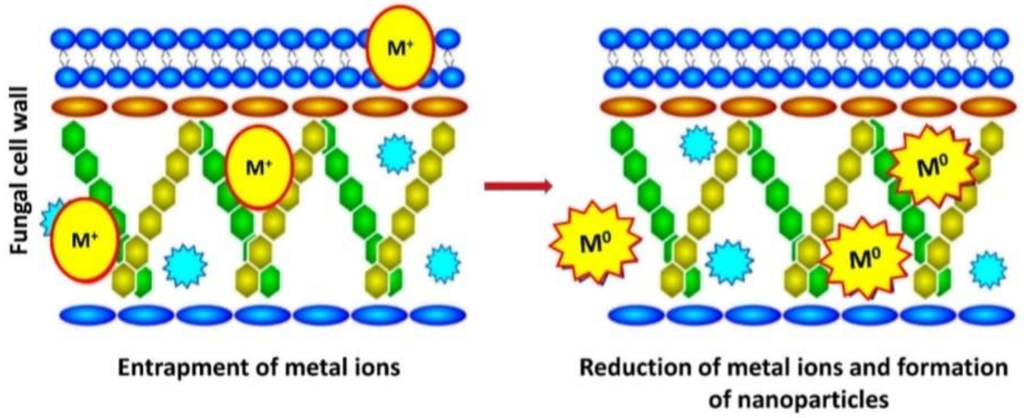

FIGURE 7: Hypothetical intracellular mechanisms for the synthesis of metal nanoparticles from *Fusarium oxysporum* (Yadav et al., 2015).

Two-step mechanism has been proposed for intracellular mycosynthesis of nanoparticles (Fig7).In first step, aqueous metal ion attached to the fungal cell surface by the electrostatic interaction between metal ionsand lysine residues.In second step, the mycosynthesis of nanoparticles occurs by the enzymatic reduction metal ions, which leads to the formation of nanoparticles (Yadav et al., 2015).

Nitya and Ragunathan, (2009) synthesized silver nanoparticles using *Pleurotus sajor.* The fungal filtrate of white rot fungi was reacted with silver nitrate solution and observed for the colour change from pale yellow to light brown. The intensity of the colourincreased as the time increased. It was then characterized by using UV-Visible spectroscopy, SEM analysisand conformed as silver nanoparticles. The spherical shaped, nanoparticle with 5-50nm was obtained. The susceptibility of silver nanoparticles against positive and negative organism was carried out by agar well diffusion method.

The silver nanoparticles which are produced from *Trichoderma harzianum* found to be more stable in nature and the nanoparticles were found in the range of 30-50nm in size and spherical in shape (Prashant Singh and Balaji Raja, 2011).

V. APPLICATIONS OF SILVER NANOBIOTECHNOLOGY

Silvernanoparticles have attracted much attention due to their potential in catalysis, biology, computing, solar cells and optoelectronic devices include cosmetics, mechanics, energy sciences, biomedical sciences, space industries, single electron transistors, nonlinear optical devices, light emitters, drug gene and photo chemical applications (Manesh et al., 2010).

Silver nanoparticles are widely used as antimicrobial agents within the health industry, food storage, textile coatings, and a variety of environmental applications, few of which are shown in Fig. 7 (Chung et al., 2016). Antimicrobial properties of silver nanoparticle are beneficial for various fields of medicine, various industries, farming, packaging, accessories, cosmetics, health, and therefore the military.

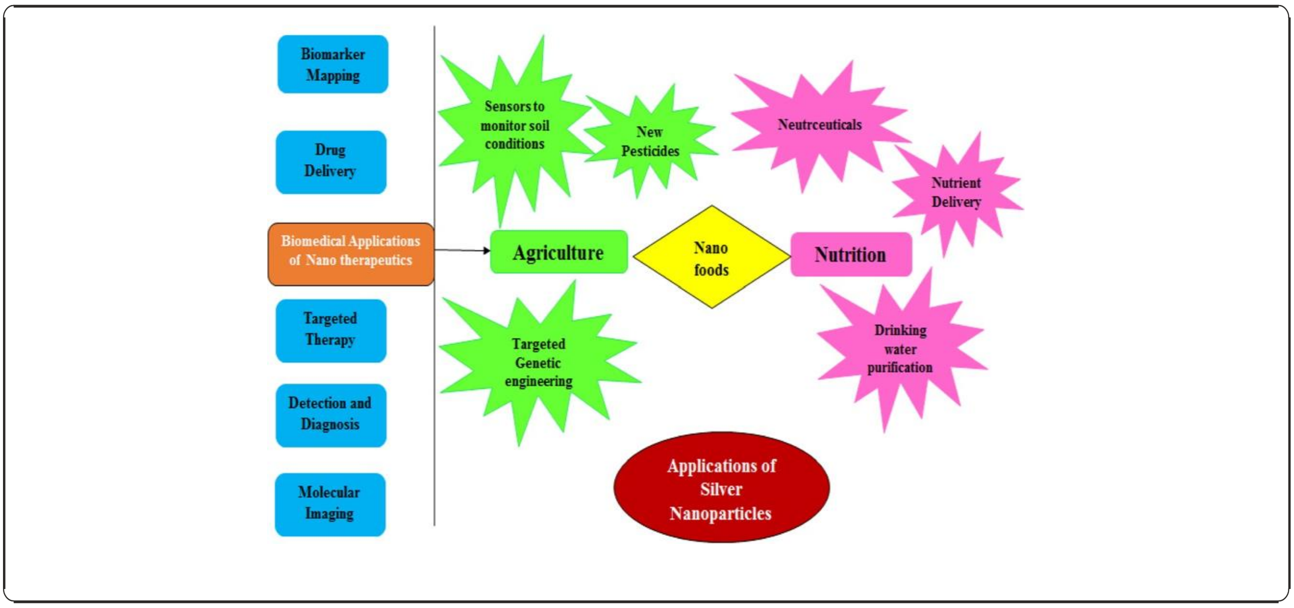

FIGURE 8: Different applications of synthesized silver nanoparticle (Chung et al., 2016)

5.1 Medical and Clinical field

Silver nanoparticles are used in surgical fields, such as urology, dentistry, general surgery and orthopedics (Roe et al., 2008). Nano-silver have been used in the treatment of wound, burns, in water –disinfecting systems, dental materials, and antibacterials, antivirals and anticancerous agents (Elliott et al., 2010). The silver nanoparticles were also used for impregnation of polymeric medical devices to extend their antibacterial activity. Silver nanoparticles are used in sensing and imaging applications, including the detection of DNA (Harper et al., 2012), selective colorimetric sensing of cystein (Ravindran et al., 2011), sensing purine nucleoside phosphorylase activity (Cao et al., 2013), and selective colorimetric sensing of mercury (Roy et al., 2011).

5.2 Agriculture

Silver nanoparticles may hold significant applications in agriculture and gardening by selectively inhibiting harmful fungi and bacteria on seeds and could provide an alternative source of fertilizer that may improve sustainable agriculture (Parveen et al., 2014).Antimicrobial property of silver nanoparticles, it is interesting to note that silver nanoparticles are predominantly used for plant disease management (Park et al., 2006). It has been reported that silver nanoparticles could be used to enhance seed germination potential in many plants (Duhan et al., 2017).The application of silver nanoparticles in plant tissue culture techniques in order to suppress microbial contaminations was initially reported by (Abdi et al., 2008).

5.3 Cancer Treatment

The silver nanoparticles synthesized by Kuppusamy et al. using Commelia nudiflora L aqueous extract showed a reduced cell viability and increased cytotoxicity against HCT-116 colon cancer cells.Silver nanoparticles composites possessed promising anticancer activity against the A549 (Human lung carcinoma), Hela (Human cervical adenocarcinoma), MCF7 (Human breast adenocarcinoma), MDAMB231 (Human breast adenocarcinoma), and SKBR3 (Human breast adenocarcinoma) cells (El-Naggar et al., 2017).

5.4 Antimicrobial activity

Silver nanoparticle is reported with antimicrobial activities which is used in disinfectants (Brady et al., 2003).Marslin et al. biosynthesized cream formulation of silver nanoparticle using Withania somnifera extract and concluded that cream had higher antimicrobial activity, hence might be utilized in low doses and fewer toxic for patient in comparison with AgNO3 counterparts (Marslin et al., 2015).

Silver nanoparticles and ZnO nanowires with polyvinylchloride, a commonly used material for catheters, and investigated the antimicrobial efficacy of the composite against *Staphylococcusaureus*, one of the most common pathogens found in catheter-associated urinary tract infection (Warren et al., 1997).Extract of C.igneus leaves- based synthesis of Ag nanoparticles have shown very strong action against bacteria and fungus as compared to standard antibacterial agents (Sataraddi et al., 2012).

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