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A Review on Eco-Friendly Formulation of Silver Nanoparticles and its Activity

Devi Bala.G[1]
[1] Department of Biotechnology,
Vivekanandha College of Engineering for Women
(Autonomous)

Girija. M[3]
[3] Department of Biotechnology,
Vivekanandha College of Engineering for Women
(Autonomous)

Dheshika. R[2]
[2]Department of Biotechnology,
Vivekanandha College of Engineering for Women
(Autonomous)

Archana. A*
*Assistant Professor,
Department of Biotechnology
Vivekanandha College of Engineering for Women
(Autonomous)

***Abstract*:-Silver had been identified as a harmless, safe,in-organic compound and had been used as an anti-bacterial/anti-fungal agent over decades. Silver had extensive application in various domains including pharmaceutical and chemical industries especially in nanoparticle form due to its efficient activity. The size of the nanoparticles varies from 1-100nm. There is numerous method available for the formulation of nanoparticles but they are not convenient and economic and also the reactives used for formulation of silver nanoparticles can cause ecological impairment. presently the researchers had a thirst in this area by a formulation of nanoparticles from naturally available resources in a most effective manner and also is an economic way. This article precise the various green-mediated formulation of silver nanoparticles and their morphology characterization, anti-microbial activity.**

Key Words: Harmless, Nanoparticle, green-mediated, anti-microbial, Economic, morphology characterization

INTRODUCTION

The term nanotechnology is characterised as structure creation, characterization, and application by changing its size and shape,[1] commonly, the size of the nanoparticles ranges from 10-100nm in diameter. It is broadly classified into two types as natural and inorganic nanoparticles The nanoparticles silver, gold, titanium, zinc and copper are grouped into organic metals and the carbon nanotubes and quantum dots are grouped into in-organic metals. Among these various nanoparticles, silver nanoparticle(AgNPs) had a unique attraction due to its metallic and biochemical activity. AgNPs also used in various applications including pharma-industry, Biotechnological, and Food industry in versatile research approaches. During Centuries, before the evidence of penicillin activity, silver had been used as a therapeutic agent. As the silver comes in nanosize (less than 100) due to their size reduction its shows considerable activity against different microorganisms besides Gram-positive and Gram-negative bacteria. In recent years the silver nanoparticles also had a great focus in the agricultural field it was used as a fertilizer as well as pesticides.Due to their nano-size, the particles can easily pass through the cuticle of the plant and showed a controlled realized activity.there are diverse methods available for the formulation of nanoparticles (physical, chemical, microbial). But they are not cost-effective and also the chemicals and microbes used for the formulation of silver nanoparticles cause harm to the ecosystem. In the development of the field of nanotechnology, the researcher had used various naturally available resources for the formulation of nanoparticles, for example, oil-cake, leaf extract, fruit extract acts as a reduction agent and capping agent. The nanoparticles synthesized by thesis methods show a prominent activity and also it becomes cost-effective compared to other chemical and microbial formulation. The researchers reported that the naturally available phytochemical compounds for example Alkaloids, flavonoid, terpenoids, saponin, etc.., present in the extract act as a reduction agent that reduces the metallic silver into a metal nanoparticle.Silver nanoparticles also used for biofilm formation and in wastewater treatment for heavy metals removal and also for the micro-organism trapping to purify the water for various utilizing activities. This review focuses on the various green-mediated formulation of AgNPs their biochemical activities and their characterization technique

VARIOUS GREEN FORMULATION METHODS

Green formulation of AgNPs using Azadirachta indica

The leaf extract of *Azadirachta indica*,(in Indian language is called neem)is used for the environment-friendly formulation of nanoparticles,[2]. The researcher had[2,3] reported that the high amount of flavonoid and terpenoids compounds presence in leaf extract act as a reducing agent that reduces the Ag^{+} ion into AgNPs particles. The researcher mixed the leaf extract and 1Mm AgNO3 in different concentrations at test tubes by brown color formation the formulation of nanoparticle had identified and observed OD at 200-800nm [3]. The analyzer reported that the very high concentration of leaf extract is not suitable for nanoparticle formulation and identified that one-third proportion of sample and the AgNO3 showed prominent antibacterial activity against E.coli and other gram-positive bacteria with zone formation of 20ql-8.66mm; 50ql-18.66mm; 100ql-22nm.

International Journal of Engineering Research & Technology (IJERT)
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Green formulation of AgNPs using piper longum (long pepper)

AgNPs synthesized by using *Piper longum* displayed extreme cytotoxic activity against the hep-2 cell line [4]. 90ml of 1Mm aqueous solution of AgNO3 and 3 ml of leaf extract was added. The mixer kept in dark and maintained by room temperature. The formation of yellow colour suggested the emergence of silver nanoparticles and the absorbence was estimated at 200 to 600 nm. The Nanoparticles were produced at various sizes 17.6nm, 29.3nm,31.6nm,37.5nm depending upon their sample and AgNO3 mixing proportions. And,[3] identified that the notable cytotoxic effect was showed in 500ųg/ml concentration of AgNPs in that 51% of the hep2-cell line were died.

Green formulation of AgNPs using leaf extract of Spartium junceum

The *Spartium junceum* solution used for nanoparticle formulation[5]. And the researcher proceeded 25ml of 1mM AgNO3 was added into 25 ml of *S.junceum* solution. The mixture was heated for 24 hours at 80^0c. By the observation of color changes from yellow to brown indicated the existence of silver nanoparticles,[6]. The morphological characters were analyzed by SPR, UV-Spectrophotometer and FTIR [7].

Green formulation of AgNPs using Impatiens-balsamia and Lantana camara

The leaf extract of *Impatiens balsamia* and *Lantana camara* used as a reduction agent for the formulation of AgNPs [8]. Different concentrations of AgNO3 stock solution were prepared (1mM, 2mM, 3mM,…) and the leaf extract of *I.balsamina* and *L.canara* was added to it and the solution was heated at 60ºC for 5 hours. The nanoparticle formulation indicates the observation color change [9]. The researcher identified that the nanoparticles synthesized by these leaf extract showed high anti-microbial activity with the zone of inhibition from 11.03 mm to 13.08 mm.[10,11]

Green formulation of AgNPs using Amaranthus viridis

Amaranthus viridis, cosmopolitan species commonly called as slender amaranth (in Indian language), leaves and seeds were edible and are used as vegetables and tops they are high in calcium, iron and found to be bonne of vitamin B and Vitamin C sources, it also showed anti-diabetic and anti-hyperlipidaemic activity [12]. *Amaranthus viridis* had used for large scale production of nanoparticle formulation had been reported. Leaves were collected, washed thrice in distilled water then washed with Milli Q water to remove water, leaves were dried in room temperature for about 2h, then 5grms of leaves were chopped and boiled with Milli Q water for 50°C at 10 minutes, then extract using Whatman No.1 filter paper. 1mM of AgNO3 (0.0421g) dissolved in 250ml of Milli Q water in the orangey colored bottle. AgNPs were synthesized by dissolving 5ml of leaf extract in 20ml of 1mM of AgNO3 and heated at 100°C, the color turns light yellow to reddish-brown confirms AgNPs present in the extract. Synthesized AgNPs were characterized under FTIR shows band range of 3423-2850nm, Scanning Electron Microscopy Energy,Dispersive Spectroscopy,(SEM-EDX)Transmission, and Electron Microscopy which measures the size of the band ranges from 5-20nm, XRD.[13] The stability of reduced AgNPs analyzed by UV-Visible spectroscopy, peak observed at 4235nm. As compared to other sources, *Amaranthus viridis* highly effective and useful, antibacterial activity against gram-positive and gram-negative, AgNPs from the *Amaranthus viridis* contains Oxides; Calcium; Silver.[14]

Green formulation of AgNPs from ceratonia siliqua (carob)

Simply known as 2 min reaction time at lukewarm for reduction of Ag^+ ions to AgNPs. Leaves were washed with distilled water, dried, sliced into small pieces and boiled in distilled water for about 10 mins, filtered the extract which was in yellow then centrifuged to remove bulk bio-materials at 1200rpm for about 5 mins. [15] AgNPs were synthesized by dissolving 5ml of extract in 1mM of 100ml of AgNO3 the mixture changes into black light which confirms AgNPs. By comparing to other carob plants, *Ceratonia siliqua* shows a quickly synthesized one. The concentration of AgNO3 and leaf extract were changed from 1-4mM and 5%-10% by volume. The characteristics analysis of AgNPs involves UV-Visible spectroscopy shows strong resonance band of surface plasmon at 420nm [16] which indicated the formation of AgNPs, FTIR measures the band at 4000 to 400cm^{-1}, SPR produced a peak near 420nm, XRD founds the crystalline size of AgNPs around 18nm which shows that the AgNPs are nanocrystalline, SEM measures the particle size ranges from 5-40nm. AgNPs could be controlled to 5-40nm by varying the extract volume and the $AgNO_3$ leaf concentration were used as a reduction agent and highly effective against E.coli.[17]

Green formulation of AgNPs using Cynara scolymus – Artichoke

species of cyclamen, cultivated as a part of the food, leaf extract were known to show anti-oxidant, anti-inflammatory, anti-allergic, anti-ulcerogenic and anti-hepatocellular carcinoma activity and they are abundant in metabolites such as chlorogenic acid, luteoline, apigenin derivatives of cynarine acid and flavonoids. Leaves were collected washed thrice in deionized water, chopped into small pieces, 200gm of leaves were added in 400ml of deionized water were added to 1L of Erlenmeyer flask heated to 100ºC for 2h then filtered using Whatman filtered paper-1, 10mM of 20ml of AgNO3 in 100ml were added to 20ml of extract in a dropwise manner, color changes brown to orange, the shreds of evidence shows the formation of AgNPs.[18] The characteristic analysis of AgNPs includes UV-Vis spectroscopy measures the particle size in the range of 200-800nm, FTIR analysis the size ranges from 400-450nm, SEM measures the particle size of the 200-223nm AgNPs was 98.47±2.04nm and the zeta potential measures the particle size at -32.3±0.8mV, and able to analysis the particle size less than 100nm.[19]

GREEN FORMULATION OF AGNPS FROM ALOE VERA

Aloe vera is Commonly known as a medicinal agent including anti-inflammatory activity, UV protection,

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Vol. 9 Issue 02, February-2020

anti-arthritis, antibacterial effect and promotes wound and burn to heal, properties constituents include lignin, hemicellulose, and pectin which were used as reducing agent.[20] 50gm of Aloe vera washed with deionized water, chopped and boiled in 50ml of deionized water for 20mins, the extract was filtered. 0.3mol of AgNO3 mixed in 20ml of deionized water with 20ml of extract and stirred vigorously at room temperature for 30mins. Nanoparticles produced at 6h, size ranges from 70.70±23;79.47±22 and 161.66±530nm prepared at 100ºc, 150ºC, and 200ºC respectively. At 12h the sizes 95.25±23;149.55±47 and 92.02±53nm at the same temperature maintained in 6h. The leaves were effective against gram-positive (*Streptococcus epidermidis*) and gram-positive (*Pseudomonas aeruginosa*).Hydroquinones act as reduction agent [21].

Green formulation of AgNPs from Ocimum sanctum: Tulsi

Tulsi was used in the medical industry found to be a great use.[22] formulation of nanoparticles involves the collection of leaves, washed in distilled water, cut into fine pieces, these pieces were added in 100ml of distilled water and stirred at 60ºC for 1h. Extracts were then filtered with Whatman filter paper-1, 5ml of extract solution dissolved in 45ml of 1mM of AgNO3. Nanoparticles were brought under characteristic analysis. UV-Vis spectroscopy measures between 250 and 800nm ranges, Surface plasmon Resonance of particles found to be the peak at 413nm and an absorbance band produced at 260nm, TEM involves the analysis of particles in the range from 4-40nm with a diameter of about 14.32±2.5nm, XRD estimated the size of 15nm.[23].

Green formulation of AgNPs using Rosa rugosa (Beach rose)

Rosa rugosa Commonly used as an ornamental plant, medicinal, cosmetic, aromatherapy properties. Preparation of nanoparticles procedure involves leaves collection, washed with distilled water, 50gm leaves in 500ml Erlenmeyer flask and boiled in 250ml ultra-pure water for about 20min, for silver nanoparticles formulation 60ml solution in 1mM AgNO3 and added with 2.5ml of leaf extract, the color changes from reddish yellow to deep red showed the confirmation of AgNPs formation, formulation did within 10 mins [24,25]. Extracts were used for herbal medicines and vitamin products. AgNPs analysis involves UV-Vis spectroscopy measures the size ranges from 300-1000nm and diameter ranges from 10-35nm, other methods for analysis included as FTIR, TEM. The absorbance increases with more leaf extract concentrations, AgNPs found to be more stable at the P^H from 5 to 10 [26].

Green formulation of AgNPs from Shorea tumbuggaia

Shorea tumbuggaia Plant extracts extremely used for ear-aches and outer shots in the arm [27]. The stem was dried for 10 days kept in a hot air oven at 60ºC for about 24-48hrs then crushed into a fine powder, 1mM of AgNO3 dissolved in plant extract and makeup to 200ml then centrifuged at 18,000rpm for 25mins. Stem bark was act as the reducing agent. The color changes from dark yellowish to brown and indicates AgNPs existence [28]. The analysis involves UV-Vis spectroscopy did by UV-2450 and measures the peak at 430nm; SEM did by Hitachi S-4500 SEM machine for image acquisition it showed the spherical shape and diameter of about 40nm, EDAX used for the analysis of weight percentage of AgNPs found to be 33.52%[30].

Green formulation of AgNPs from Tea Leaf Extract

The reaction was carried out for 12h at room temperature is reported. Here tea leaf extract acted as a reduction agent. Nanoparticles were formulation by the following procedure involves of 16g of dried tea leaves were added in 100ml of ultra-pure water in 250ml of Erlenmeyer flask boiled for 5mins, 70µl of AgNO3 (10mM) were mixed with 14.25ml of tea extract in a drop wise manner and followed by vigorous stirring, the color changes from brown color indicates the existence of AgNPs. formulation AgNPs were characterized by TEM; XRD; FTIR; thermo-gravimetric analyzer, Zeta potential analyzer, synthesized nanoparticles were found to be spherical and range in size from 20-90nm, shows the activity against E.coli. AgNPs were produced at the competence of 99.1%; 99.7%; 99.9%; 99.8%; 94.6% and 95.3% with 5%, 10%, 25%, 50%, and 100%(v/v) tea extract respectively.[31] FTIR shows that the synthesized AgNPs had the involvement of amides, carboxyl, amino group, and polyphenol. And also Synthesized AgNPs were discovered as low as compared to the PVA-coated AgNPs, uncoated; commercial AgNPs which have good stability due to their functional group of the tea extract. Synthesized nanoparticles show the antibacterial activity against E.coli.[32]

Green formulation of AgNPs using Tectona grandis

Tectona grandis, the bark had been used as an anti-bacterial compound 5-hydroxy-1,4-naphthalenedione (Juglore)shows antibacterial activity against *Listeria monocytogenes* and methicillin-resistant to *Staphylococcus aureus* (MRSA) [33] .and used for the treatment of anemia [34]. Reducing agents in the plant constituents like carbohydrates, fats, enzyme, flavonoids, terpenoids poly benzols, and alkaloids. Seeds had collected, before washing the outer coating was stripped and cleaned, dried at ambient temperature for about 3-4 days then crushed into fine powders. 5g of powdered seeds were taken in an Erlenmeyer flask of 250ml and it was added with 50ml of double-distilled water, boiling at 80ºC for 15-20mins, extract was filtered using muslin cloth, 1mM of AgNO3 in double distilled water were prepared at the ratio of 1:4 and mixed below to boiling point and the reaction conducted in dark place with a help of magnetic stirrer at 800rpm, the extract turned colorless to yellow to reddish-brown color within 1h analyzed by UV-Vis spectrophotometer and scanned ranges from 300-600nm measures the maximum absorbance at 440nm[35] it showed the formation of nanoparticles, in SEM the images were blurred and could not able to take image at 100nm of particles, therefore, FESEM were did. The FESEM-EDX indicates 94 per cent of Ag and 6 per cent of oxides. TEM analysis at the ranges of 10-30nm [36].

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Vol. 9 Issue 02, February-2020

Green formulation of AgNPs from tomato leaf

Leaves of rosemary (*Rosmarinus officinalls*) were collected and washed with sterile distilled water, 5grms of leaves were added to 100ml of distilled water and boiled for 5 mins. The extracts are filtered with Whatman filter paper and centrifuged for about 5min at 4000rpm, the supernatant used for formulation of AgNPs, 1mM of AgNO3 added in a drop wise manner in 50ml of extract and incubated for 18h at room temperature, centrifuged 10mins at 10,000rpm. The color changes from yellowish-brown to brown after 24h of incubation indicates the formation of nanoparticles. The synthesized nanoparticles were analyzed under UV-Vis spectroscopy which measures the particle size at 300-400nm in a resolution of 1nm absorbance band located around 427nm. Leaf extract acted as the reducing agent, synthesized nanoparticles harmed wheat seedling and vegetable growth of tomato and wheat plants and enhance the activity of peroxidase and MDA.[37]

Green formulation of AgNPs using Capsicum frutescence

Capsicum peppers are produced capsaicin is ubiquitous. The capsaicinoid alkaloids were responsible for pungency. The leaf extract reduces as well as stabilizes the Ag^{+} ions and which contains secondary metabolites. The crystalline form of silver nanoparticle was analyzed by XRD. The bactericidal susceptibility and antibacterial activity are achieved by the method of disc diffusion for the synthesized nanoparticles. The resulting plates observed for *E.coli* which indicates gram-negative strain and observed *B.subtilis* which indicates gram-positive strain. After they incubated the plates at 37^{0}C for 24h. The diameter of the area around the well was analysed for antibacterial activity. SEM observed the size of the AgNPs, with a range of 15-20nm. The antibacterial activity mechanism was electrostatic interactions and cell wall disruption. The synthesized AgNPs high activity against gram-negative and moderate against gram-positive.[38].

Green formulation of AgNPs using Clitoria ternatea and Solanum nigrum

The silver nanoparticles' activity contains many materials used in medicine and in burn treatment and arthroplasty to reduce infections. It also prevents bacteria colonization on prostheses, catheters, vascular grafts, dental materials, stainless steel materials, and human skin. The *Solanum nigrum* extract as a reduction agent which is responsible for infant mortality. The extract was added with 1Mm AgNO3 and it was centrifuged. Then the pellet was taken and washed thrice with 5ml distilled water and it analyzed by FTIR. The enzymes and proteins are not capping with AgNPs. The range of absorbance was measured at 420-440nm. *Clitoria ternatea* and *Solanum nigrum* silver nanoparticles stood against the pathogen's growth. [39]

Green formulation of AgNPs using Leaf Extracts of Pimenta dioica (Allspice)

The *Pimenta dioica* (Allspice) leaf extract was resistant to spoilage. The life span of the extract was until 3 months. The leaf extract of pimento dioica has antiseptic, anesthetic, and other medical properties. Several researchers have reported no beneficial results from sun-dried leaves. The extract act as a reduction agent that is mixed with AgNO3. The synthesized nanoparticles were analyzed by UV spectrophotometer and AFM. The nano-surf Easy scan-2 software was used to analyze the AgNPs from the leaf extract. The largest size of AgNPs from fresh leaves in the ratio of 1:1 and the smallest size of silver nanoparticles from dried leaves.[40]

Green formulation of AgNPs by an oak leaf and fruit extracts (Quercus)

The author had reported that The oak leaf extract and its fruit extract had been collected and washed with distilled water to remove the unwanted particles and sun-dried for 2 days. The dried matter was crushed with mortar and 3g of ground fruit was boiled with 100ml distilled water for 10 min in 60℃. The blend of leaves and fruits was filtered using Whatman no 1 filter paper and proceed in dark at 4℃. the 1ml filtrate was added with 30ml of 1Mm AgNO3. After 80 mins the resulting color appeared in deep brown. Which indicates the formulation of nanoparticles than leaf extract. The pH was adjusted using NH3PO4 and NaOH. The synthesized solution was observed by UV spectrophotometer. It showed an absorbance peak at 415–445nm. Additionally, the solution was centrifuged for 5 min at 15,000 rpm. Light yellow to brown for leaf extract and pale brown to dark brown for fruit extract depending on concentration. It showed that silver nitrate reduction to silver nanoparticles. [40].

CONCLUSION

Based on the above discourse it can be stated that the formulation of silver nanoparticles paved the way for biomedical nanotechnology for developing effectual anti-microbial drugs in future perspective. By the emergence of green formulation, it largely scaled-up silver nanoparticle formulation over physical and chemical methods in a cost-effective and eco-friendly manner. The morphology characteristics and activity of AgNPs varies according to their reaction parameters. This review provides extensive knowledge of the green-mediated formulation of silver nanoparticles being introduced over the last ten years.

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