Egypt. J. Chem. **Vol. 65**, No. 5 pp. 575 - 589 (2022)

Egyptian Journal of Chemistry

http://ejchem.journals.ekb.eg/

A Review on Different Plants Extract Mediated Silver Nanoparticles: Preparation, Antimicrobials, and Antioxidant

M.A. Betiha[a], Z.M. Kheiralla [b], A.S. Mansour [c], A.N. Emam, Samy B. El-Henawy[a], Eslam A. Mohamed[a] and N.A. Negm [a*]

[a] *Egyptian Petroleum Research Institute, Cairo, Egypt*
[b] *Botany Department- Faculty of Women for Arts, Science and Education Ain Shams University, Asmaa Fahmy Street Heliopolis, Cairo, 11586, Egypt*
[c] *National Institute of Laser Enhanced Sciences (NILES), Cairo University, Cairo 12613, Egypt*
[d] *Refractories, Ceramics and Building Materials Department National Research Centre (NRC.) Cairo, Egypt*

Abstract

Silver nanoparticles have shown success in many applications, especially in the field of biochemistry, by controlling the shape and size of these nanoparticles, which had a significant impact on the diversity of their antimicrobial properties. Many different shapes and sizes of silver nanoparticles can be prepared by various techniques, the most important of which is the use of capping agents, where the role of capping agents is not limited to controlling both sizes and shape only but extends to the stability of nanoparticles nanostructures. In addition, the type of capping agent has an influential role in the surface efficiency of the formed silver nanoparticles. However, multiple concerns have been raised regarding the environmental safety and human health impacts of the use of chemically manufactured capping agents. This review included the manufacture of silver nanoparticles using aqueous extract of some plants, flowers, or fruits, and their applicability and activity in various fields such as antioxidants and antibacterials were examined. Also, some of the most common and popular chemical and physical methodologies are initially described, and the advantages and disadvantages of using these methods to prepare silver nanoparticles are considered. Green synthesis methodologies have been discussed in detail with emphasis on their benefits and applications. Much of the recent literature related to the use of plant extracts have been addressed, and the effects of basic reaction parameters, such as temperature, pH, precursor, and extract concentration, on silver nanostructure size and morphology have been reported. Moreover, current challenges related to the green synthesis of silver nanostructures and future directions have been identified. In summary, the review aims to demonstrate the true potential of green nanotechnology towards the synthesis of silver nanostructures in various morphology and the possibility of moving away from current chemical techniques towards more environmentally friendly, less hazardous, simpler, and high efficient material as antimicrobial activity and Anti-oxidant.

Keywords; Silver nanoparticles; surfactants; Capping agent; antibacterial

1. Introduction

Nanotechnology is one of the future technologies that will depend on the human race to simplify its life. This technology includes the manufacture and application of nanostructures of various materials in many life applications. Manufactured and produced materials in the nano (1–100 nm) range show amazing physical and chemical properties with the possibility of using small quantities of them compared to large-scale materials. Multiple nano shapes also show different properties, especially in the fields of physics and the medical field, even if the size of the particles is equal. Researches in the field of nanotechnology are on the rise, especially in the medical field, environmental conservation, and water treatment. The global market value of nanotechnology has reached nearly $49 billion, and this value is expected to rise to nearly $76 billion this year [1].

In short, nanometric materials can be obtained in two ways; the first is the top-down approach. In this

*Corresponding author e-mail: nabelnegm@hotmail.com.; (Nabel A. Negm).
Receive Date: 06 October 2021, Revise Date: 08 November 2021, Accept Date: 15 November 2021
DOI: 10.21608/ejchem.2021.99747.4637

approach, nanometric materials are obtained using physical processes such as milling, plasma etching, grinding, lithography, etc. The high energy consumed to get nanomaterials by these methods represents one of the main shortcomings of this process, besides the inability to obtain nanoparticles smaller than that sometimes hinders the use of this method [2, 3]. Second, the bottom-up approach includes starting with ions or particles of materials to be prepared in the nano-scale. This approach is distinguished from the previous one by the ease of controlling the size of the nanoparticles and adjusting their size as well as their shapes. Several methods are used in the bottom-up approach, including sol-gel synthesis, microwave, chemical vapor deposition (CVD), green synthesis by plant extracts, laser pyrolysis, and others [4-31]. Physical methods for preparing nanomaterials apply the use of thermal, electrical, and radiation energy to dissolve, evaporate or condense nanoparticles. Chemical processes are the most common and most suitable for preparing nanoparticles in the desired shape and size, where chemical ion reducing agents and various capping agents are used to achieve the stability of the prepared nanomaterials such as hydrazine polyphenols, citrates, protein, and surfactants. Biological methods for preparing nanoparticles usually use extracts of leaves, seeds, or even fruits, and sometimes microorganisms such as algae, fungi, and proteins [32, 33].

Silver nanoparticles occupied the widest range in studies related to the fields of medicine, biochemistry, food preservation, and the environment, and they showed significant antimicrobial activity in addition to their photocatalytic efficiency in the degradation of organic dyes [19, 31, 34, 35]. Emam et al. [36] synthesized silver nanoparticles using chitin as biopolymer (Ag@chitin) in basic media. SEM analysis indicated a good uniform dispersion of silver nanoparticles within biopolymer matrix, chitin. By the same group, many nanoparticles were fabricated in the presence of chitin, ascorbic acid, sodium alginate, and pectin [37-39]. Silver nanoparticles or silver blended zinc oxide have been incorporated into the fabric, especially cotton, with different methods in order to reduce the proliferation of bacteria and germs [40-43]. Several studies have reported that the number and position of surface plasmon resonance analysis peaks differ according to the shape and size of silver nanoparticles, as these particles tend to show different physical and biological properties that depend on their size and shape [44-46]. Rapid advances in nanotechnology have allowed precise size control of silver nanoparticles to improve the stability of colloidal emulsions and maintain their catalytic efficiency and plasmonic properties [47].

The high energy of the surface of silver nanoparticles leads to agglomeration or aggregation. Therefore, there are many studies to avoid this accumulation. Among these, surface-active agents (surfactants, especially cationic surfactants), plant extracts, and sometimes polymers that dissolve in water to cause a large dispersion of silver particles in their solutions by encapsulating silver nanoparticles or surrounding them. The encapsulating results in reducing charges on the surface of silver nanoparticles and increasing their compatibility with the nature of the solution [48].

One of the promising applications of green chemistry in the preparation of silver nanoparticles is the use of plant extracts. Plant extracts have a dual action as a capping agent (for morphology control and size stabilization) and a reducing agent. Industrially, surfactants are used in the production produce silver nanoparticles to prevent their accumulation (increasing their exposed surface area and increasing the stability of the colloid) [49].

2. Synthesis of silver nanoparticles

There are many sealing agents that have proven good efficacy in stabilizing silver nanocolloids, including phenolic polymers, graphene oxides, peptides, polymers, fatty acids, and N-acyl tyramines.

It is always interesting to use plant extracts in the production of silver nanoparticles because of their good effect on the environment and their economy, as they have a double effect during preparation. Biological molecules contain active chemical groups that reduce silver salts (steroid, sapogenin, carbohydrate, and flavonoid molecules). Other chemical groups in plant extracts linked to the nanostructure of silver particles, such as carboxyl and amine, provide stability to solutions of silver particles[50]. The use of Acalypha hispida leaf extract resulted in the formation of silver nanoparticles with spherical shapes with dimensions (20-50 nm) [51] (Figure 1). The authors note the time taken to complete the preparation of silver nanoparticles is 45 minutes. The authors examined the stability of the prepared silver particles after being prepared for an estimated period of 30 days under normal atmospheric conditions. They found a peak intensity decreased with an increase in the incubation period, which was explained by the accumulation of some silver particles, which led to the rise in the size of the silver nanoparticles.

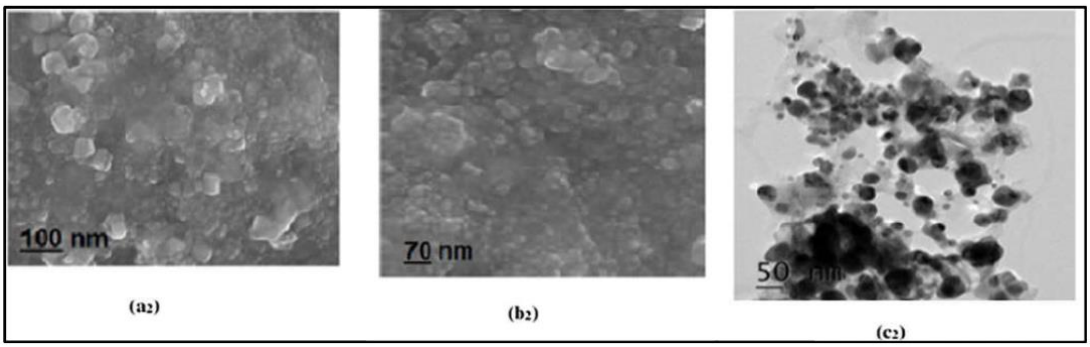


Figure 1. TEM image of silver nanoparticles prepared using Acalypha hispida leaf extract [51], a, b, c represents different amounts of silver and extract of Acalypha hispida leaf.

Alomar et al. [52] have attempted to prepare silver nanoparticles using the green chemistry technique by using extract of peganum harmala leaves as a reducing and stabilizing agent. They also examined the activities of silver particles as antigens for some pathogenic strains. After washing and drying the leaves of the peganum harmala, the dried material is soaked in boiled distilled water in a ratio of 1:10 for 12 hours. Then, peganum harmala mixture was filtered, and take about 5 ml to add to 50 ml of silver nitrate (1.0 mmol) at 60° C under stirring until the start of color change was observed. When the color of the mixture is stable (brown), the reaction is separated, which takes about an hour, and the silver nanoparticles are stored in the dark to reduce further reduction or aggregation of particles. Dynamic light scattering (DLS) showed the mean average size of 184 nm with two major sizes at 240 and 30 nm with ratios of 94.8% and 5.2%, respectively. The UV-vis spectrum of silver nanoparticle- peganum harmala leaves extract showed an emission peak at 447.7 nm during UV-excitation at 320 nm. The TEM image showed the formation of less agglomeration spherical nanoparticles (Figure 1). The silver nanoparticle-peganum harmala leaves extract showed an inhibition zone of 65 mm and 50 mm against Gram-negative pathogenic bacterium E. coli and Gram-positive bacteria S. aureus and Bacillus cereus, respectively.

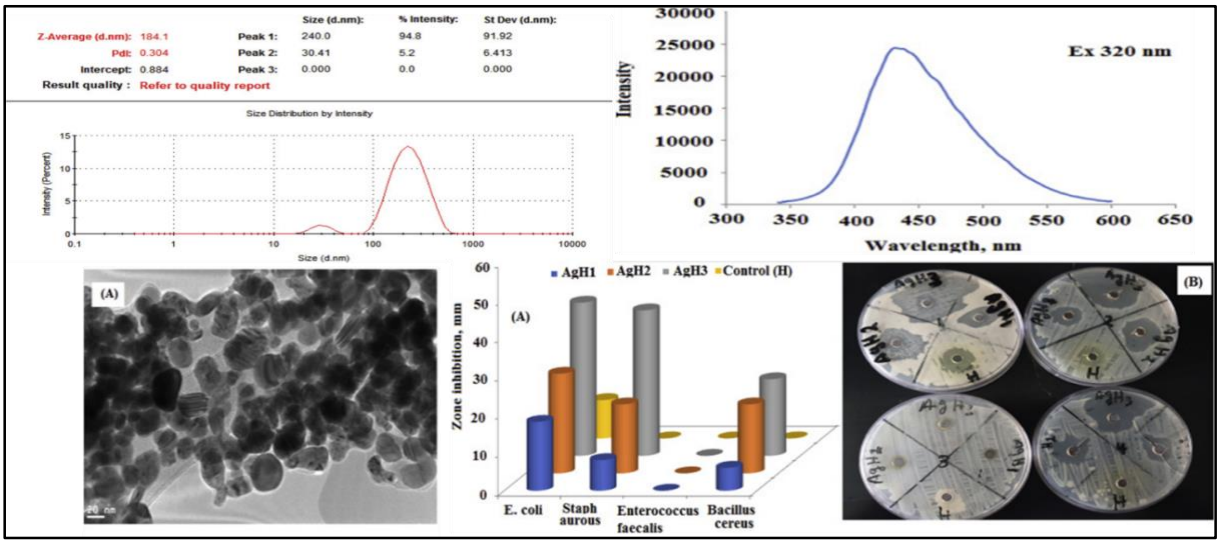


Figure 2. DLS data, photoluminescence spectrum, and TEM image the green synthesized silver nanoparticle by aqueous extract of Peganum harmala leaves [52].

Valsalam et al. [53]presented a study about Musa acuminata Colla flowers to synthesize silver nanoparticles. After drying the leaves, the Soxhlet apparatus was charged with 25 g of dried leaves and extracted with ethanol or water. The silver nanoparticle was prepared by stirring the extract of M. acuminata colla flowers (10 ml) were added to 1.0 mmol $AgNO_3$ (90 ml) at 25 °C. The silver nanoparticles were collected by centrifugation (10,000 rpm) for 30 min.The activity of

biosynthesized silver nanoparticles against ESBL gene-producing bacteria was tested.The silver nanoparticle showed good antibacterial activities against Enterococcus faecalis, Proteus mirabilis, Pseudomonas aeruginosa, and Klebsiella pneumoniae and moderate activity against Staphylococcus aureus.

Bindhu et al. [54] used the extract of Moringa oleifera flower to reduce and stabilize monodispersed silver nanoparticles. The extract of Moringa oleifera flowers was obtained by soak flowers 20 g of cleaned Moringa oleifera flowers in boiled distilled water. The silver nanoparticles are obtained by adding 1 mmol of silver nitrate to 2 ml extract of Moringa oleifera flowers (reddish-brown color). TEM images show monodispersed spherical nanosilver of size 13 nm. Silver nanoparticle- extract of Moringa oleifera flowers were produced the inhibition zone of 17 mm and 29 mm against Klebsiella pneumoniae and Staphylococcus aureus, respectively.

Raja et al. [55] achieved the obtaining of silver nanoparticles for the first time using leaf extract of Calliandra haematocephala.The authors cleaned, dried, and ground Calliandra haematocephala leaves, added water to them, boiled the mixture for ten minutes, and filtered it. In order to obtain silver nanoparticles, a solution of silver nitrate (mmol) was added to 90 ml of plant leaf extract, and the temperature of the mixture was raised to 80 °C under stirring for 10 minutes. The average particle size was 70 nm and showed Uv-vis peak at 414 nm (Figure 3). One of the plant extract components is gallic acid, which acts as a reducing agent for silver nitrate during the formation of silver nanoparticles. Silver showed antibacterial activity against Escherichia coli, and also the silver nanoparticle was used as a probe to detect the presence of hydrogen peroxide (H2O2) in different samples.

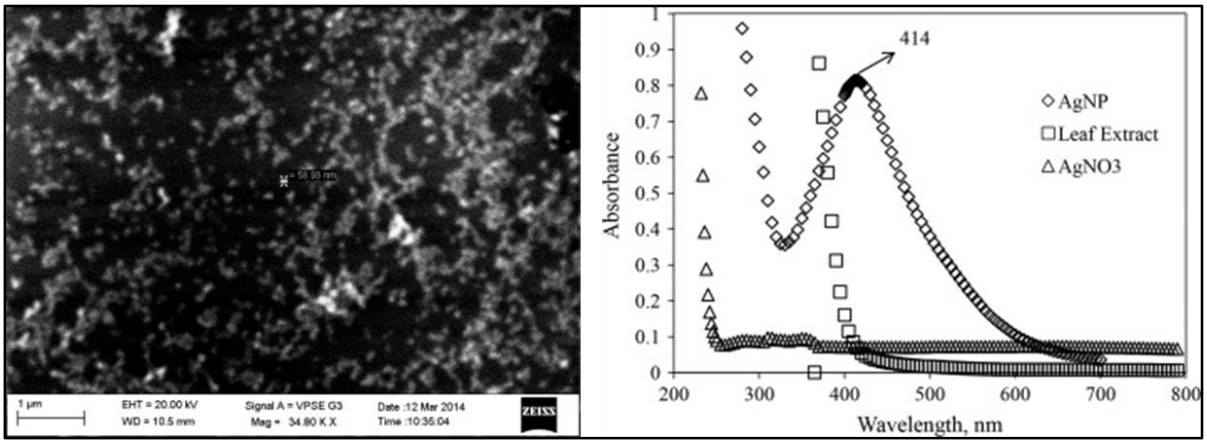


Figure 3. SEM image and UV-vis spectra of SNPs synthesized by the Calliandra haematocephala's leaf extract[55].

Nazeruddin et al. [56] used Azadirachta indica leaf extract as an alternative to surfactants for the production of silver nanoparticles. The authors note the rapid preparation of silver nanoparticles (approximately 3 minutes). The TEM and SEM image indicated the formation of different sized and well-dispersed spherical nanoparticles (Figure 4). The synthesized AgNPs showed antimicrobial activity against gram-positive bacteria Bacillus subtilus.Jha and Shimpi [57] used the extract of M. charantia fruits to rapidly fabricate crystalline and spherical silver nanoparticles (5 min) (Figure 5). The authors noted that flavonoid and protein molecules worked as reducing and stabilizing agents, respectively, during the fabrication process. The TEM image showed the nano-spherical morphology of silver nanoparticles (16 nm).Kumar et al. [58] have studied the use of Araza fruit extract and its anti-oxidant activity in the preparation of silver nanoparticles. The authors note that the UV-Vis peak depends on the temperature, pH, and reaction time. The TEM analysis revealed the formation of spherical, crystalline, and dispersed silver nanoparticles with average sizes of 15-45 nm. The main phytochemicals in the Araza fruit are malic acid (HO2CCH2CH(OH)CO2H), citric acid (HOC(COOH)(CH2COOH)2),and carotenoids [59, 60]. The silver nanoparticles capped with the Araza fruit extract containing -COOH and -OH groups generate stable nanoparticles and increase the anti-oxidant efficacy of silver nanoparticles due to the synergistic interaction of silver atoms with the Araza fruit extract.

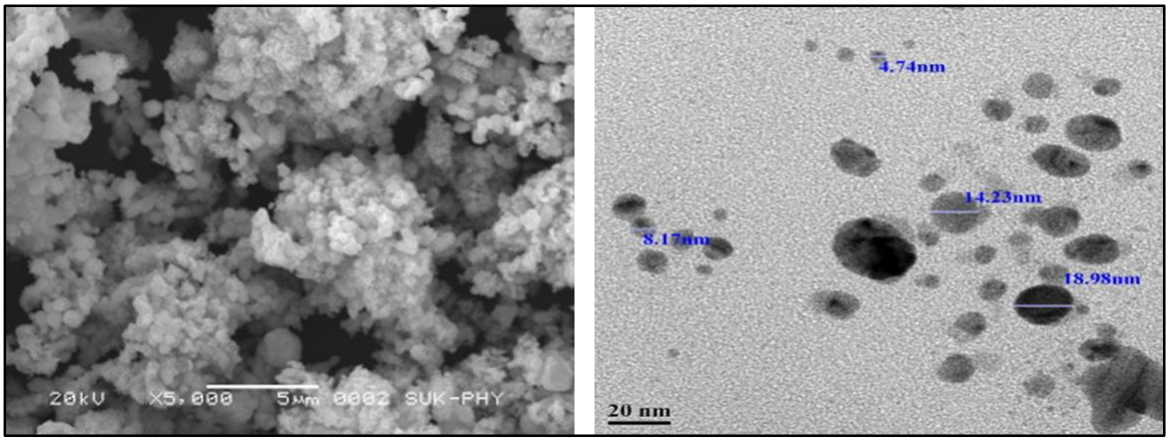


Figure 4. SEM and TEM images silver nanoparticles [56]

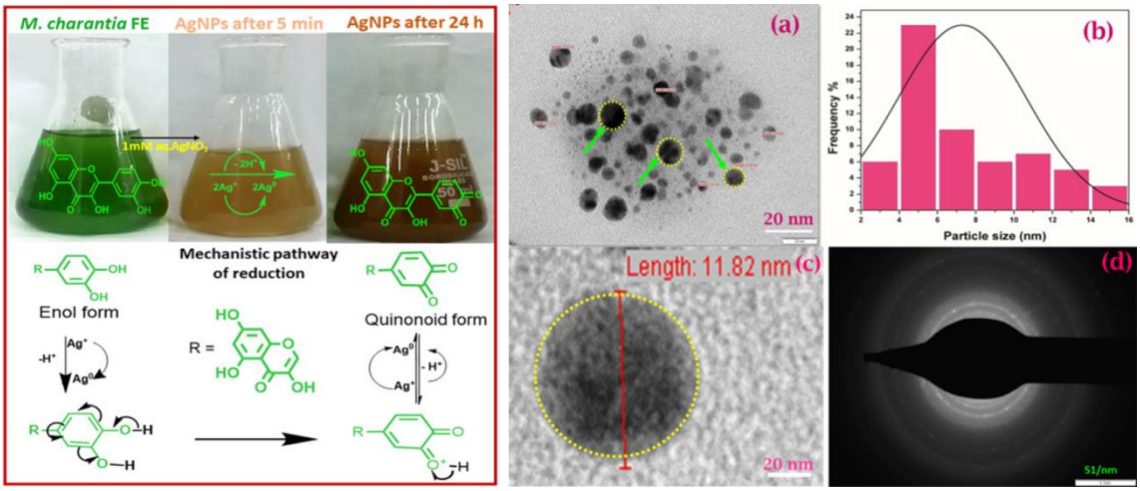


Figure 5. Mechanistic of reduction of Ag^{+} to Ag^{0}, and TEM image AgNPs with spherical morphology [57]

S. Shakya et al. [61] reported the preparation of silver nanoparticles with high antibacterial and anti-oxidant activity using Helicteres isora stem bark extract. The UV-Vis of silver nanoparticles was observed at 419–431 nm, while the steroid sapogenin binding silver atom was identified using FTIR spectroscopy. Through the availability of the alcohol and alkene groups in Helicteres isora stem bark extract, the chemical bonding between silver ions and the Helicteres isora stem bark extract is made. This binding enables controlling the particle size (25.55 nm) and dispersion of the silver nanoparticles. Biocomposite silver particles have shown multiple functions as anti-oxidant and antimicrobial. The nanosilver coated with stem bark extract solution showed a dose-dependent cytotoxic effect on KB cells. Where significant mortality was shown after exposure to silver nanoparticles for 108 hours; thus, the authors reported that colloidal silver is not acutely toxic to Artemia. The authors recommend scaling up this green method for industrial production and manufacturing of ultrafiltration membranes and food packaging.

Ahmed et al. [62] reported a quick and simple applied approach using Azadirachta indica aqueous extract to prepare silver nanoparticles. Azadirachta indica plant extract acts as a reducing agent as well as a capping agent. The chemical groups responsible for the reduction of silver ions in the plant extract are NH2 and OH groups. The TEM analysis revealed that silver nanoparticles are well dispersed, most of them are spherical in shape, and few have irregularly shaped structures. The nanoparticles are homogeneous and spherical, and the particle size corresponds to the DLS analysis with an average diameter of 34 nm (Figure 6). The synthesized silver nanoparticles showed efficient antimicrobial against both S. aureus and E. coli bacteria.Alkhalaf et al. [63] studied the effect of silver nanoparticles prepared using Nigella sativa extract on anti-diabetics and anti-inflammatory. The plant extract (Nigella sativa) was prepared by placing 100 g of Nigella sativa seed powder in a Soxhlet device pre-charged with ethanol

(70%). The amount of the final extract is 32%, then the extract is concentrated under reduced pressure.Silver nanoparticles were also obtained by adding 50 mmol of silver nitrate solution to the extract at 100 °C.The authors report that Nigella sativa extract capped silver has a promising anti-diabetic effect, with particular reference to diabetic neuropathy, through its ability to attenuate hyperglycemia, oxidative stress, inflammation, and apoptosis.Hashim et al. [64] have used the green synthesis method to prepare silver nanoparticles from silver nitrate compound, using Vitis vinifera fruit skin extract as a reducing agent. The results showed that silver nanoparticles were well-formed by mixing the methanolic extract of Viti's vinifera fruit with silver nitrate. The TEM images showed that shapes were a circle, triangle, and oval, but most of them were a circle, and the sizes of the nanoparticles were in the range of 30 - 65 nm. It has been observed that silver nanoparticles are able to act as anti-microbials (Staphylococcus aureus, Listeria monocytogenes, and Staphylococcus epidermidis); moreover, the anticancer screening of silver nanoparticles was found to effectively inhibit the proliferation of cancer cells (HeLa cells and MCF-7 cells) (Figure 7).

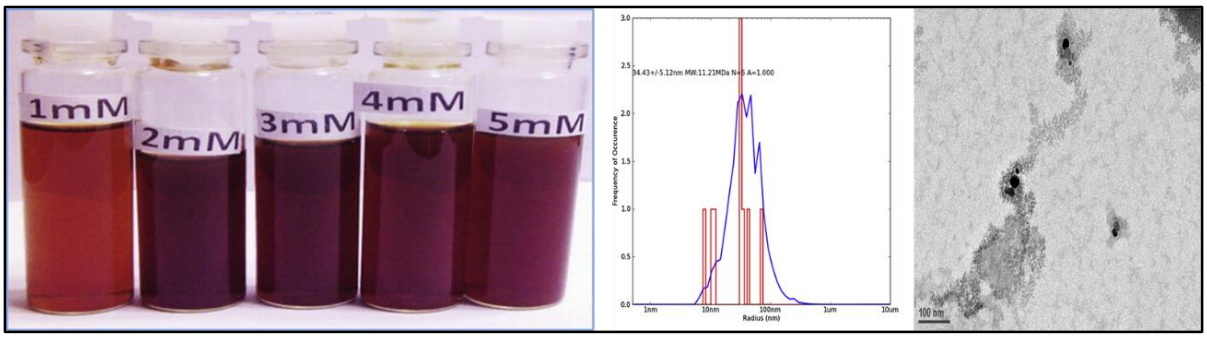


Figure 6. Optical images and DLS and TEM images of synthesized silver nanoparticles [62]

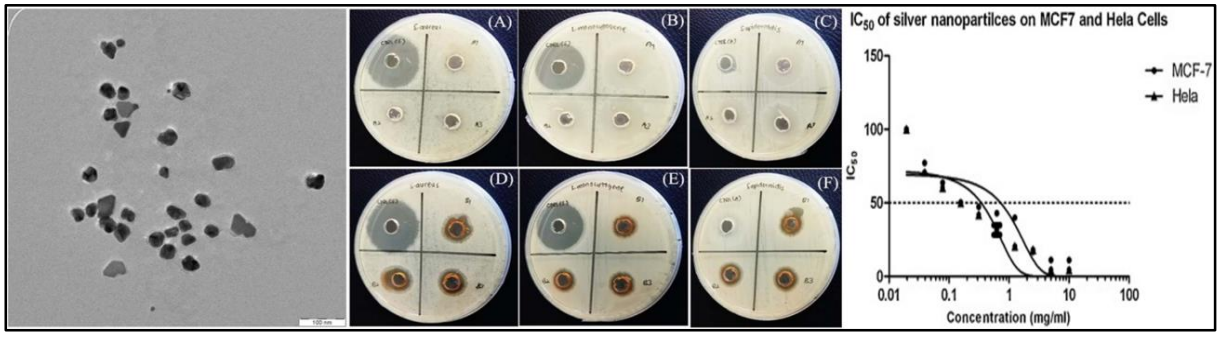


Figure 7. TEM, antibacterial, and cytotoxicity assay of grape tannin mediated silver nanoparticles[64].

Maity et al. [65] have reported a green synthesis of silver nanoparticles from silver nitrate and arabinoxylan (isolated from the green stem of Andrographis paniculata). The UV-visible spectra of silver nanoparticles showed that the maximum intensity of the absorption peak (450 to 410 nm) was by conducting the reaction at 75 °C. Also, the absorption spectrum analysis showed that the intensity of the absorption increases with time due to the reduction of silver ions to the silver element even 90 minutes, indicating a near-complete decrease of Ag + (ions) to Ag0 (element). HR-TEM images of the as-prepared silver revealed that the silver particles are spherical in shape with an average size of 24.5 nm. The silver nanoparticle-arabinoxylan compound showed tremendous antibacterial activity against Streptococcus pneumoniae and Escherichia coli and good antifungal against Candida albicans.The silver-arabinoxylan complex causes damage (4% hemolysis) to human erythrocytes at 12.5 mcg/mL at LD50 dose (Figure 8).

Tamilarasi and Meena [66] prepared silver nanoparticles using silver nitrate as a chemical precursor and aqueous extract of fresh leaves of Gomphrena globosa (Globe amaranth) as reducing and stabilizer agents. The active phytochemicals compounds (ketone, aldehyde, terpenoid, flavone, amide, phenol, carboxylic acid, and ascorbic acids

compounds) present in the leaves cause silver ions (Ag+) to be reduced to metallic silver nanoparticles (Ag0), and the formation of silver nanoparticles has been confirmed by changing the color of the mixture. The Gomphrena globosa extract was prepared from the finely chopped and dried leaves by adding 10 gm to 100 ml deionized water and raising the mixture's temperature to 65 °C. When the water turns greenish-yellow, the mixture is cooled and filtered. Silver nanoparticles were prepared by adding 5 ml of G. globosa leaf extract to 50 ml of aqueous silver nitrate solution (2 × 10−3 M) and stirred for 1 hour at room temperature.

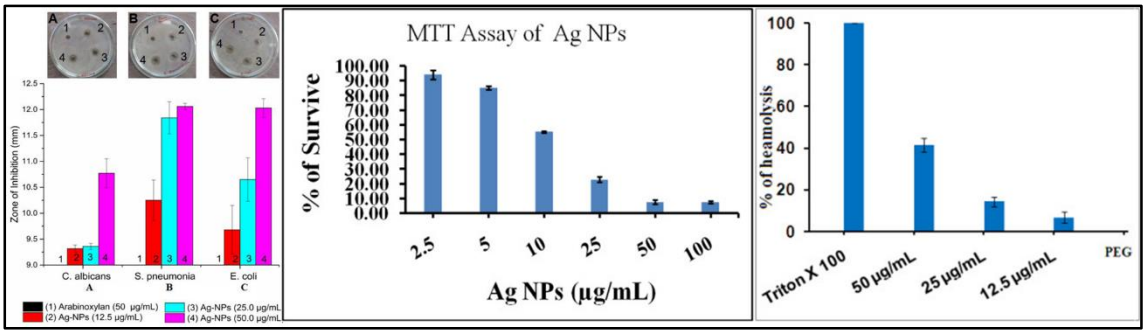


Figure 8. Antibacterial activity, 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyl-2H-tetrazolium bromide (M.T.T.) Assay and Haemolysis assay and of silver nanoparticles -arabinoxylan conjugates [65].

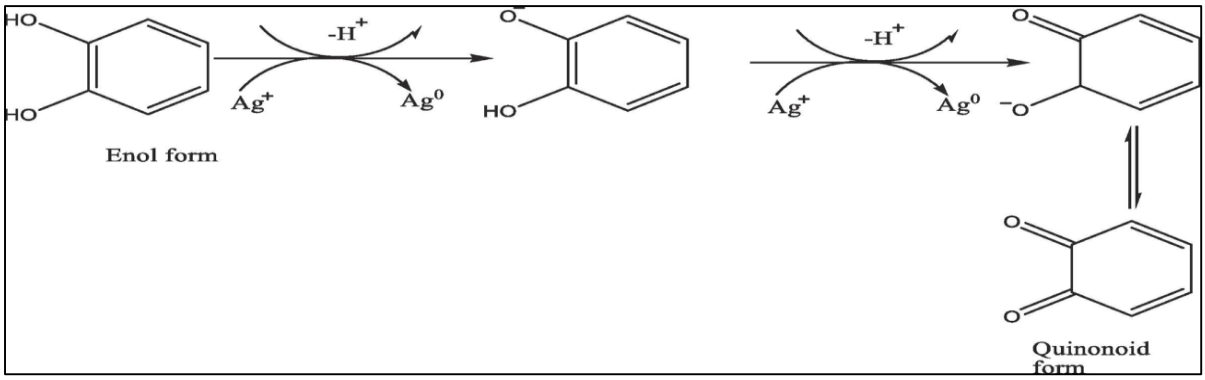
HR-TEM images show a mixture of silver nanoparticles; Spherical triangle, hexagon, and triangle. These shapes are very similar to silver nanoparticles made from Cannonball leaves. Many forms may result from the presence of different bioactive compounds in Gomphrena globosa leaf extract, such as polysaccharides, polyphenols, and proteins [67-69]. The antibacterial activity showed that the silver nanoparticles synthesized by adding a 5 mL leaf extract concentration had great activity due to the low particle size (15.6 nm) than others.

Katta and Dubey [70] discussed silver nanoparticles' optical and morphological properties prepared using marigold flower extract. To prepare the leaf extract, the flower leaves were separated from the fresh marigold flowers, and 10 gm of them were added to boiling water (200 ml) for a third of an hour and then separated by filtering. The resulting extract was mixed with 5 mL of 0.1M AgNO3 and left for two days in the dark to slow the removal process. Silver nanoparticles were harvested by centrifugation. The synthesized silver nanoparticles had a crystalline nature. The UV-vis study showed a broad peak at 420 nm dedicated to the surface plasmon resonance induced by silver nanoparticles. The photodegradation of rhodamine B dye by silver nanoparticle-mediated flower leaves showed good photocatalytic activity degradation due to the quantum confinement effect.

Ravichandran et al. [71] presented an eco-friendly, one-step, cost-effective and non-toxic method for the preparation of silver nanoparticles. The bio-inspired synthesis of silver nanoparticles was done using an aqueous extract of Parkia Speciosa leaves. Parkia speciosa belongs to Fabaceae family. It should be mentioned that with the administration of Parkia speciosa pod extract with chloroform to a rat with alloxan-induced diabetes, a decrease in blood glucose level was observed [72]. To produce the extract from fresh leaves of Parkia speciosa, 25 gm of thoroughly washed leaves were weighed and added to boiling water (100 ml) for 5 minutes. This is followed by filtration, centrifugation for 2 minutes at 3000 rpm, and the extract stored at 4 °C. Silver nanoparticles were prepared by adding 1 ml of Parkia speciosa leaf extracts to 1 ml of 0.01 M AgNO3 solution, then increasing the volume of the solution with distilled water to a volume of 10 ml and keeping it at room temperature for 24 hours to complete the reduction process.

The authors investigated the mechanism of the formation of silver nanoparticles using aqueous Parkia speciosa leaf extract. The authors reported that phenols and flavonoids are the ones that perform the process of reducing silver ions. The most active of these substances are flavonoids. The protein molecules are responsible for the non-aggregation of the formed silver nanoparticles as they act as a covering agent. The enol moieties (C=C(OH)) in flavonoid and phenol compounds may release electrons by breaking the hydroxyl bond, and the liberated electron can be used to reduce silver ions to silver element [73, 74] (Scheme 1).

The authors concluded that the silver nanoparticles-P. Speciosa leaf aqueous extract have an amazing antibacterial effect similar to streptomycin, and they also showed remarkable activity in removing free radicals. In addition, it had a catalytic activity in the photodegradation of methylene blue dye under solar radiation and pH 11.



Scheme 1. Proposed mechanism of aqueous extract P. Speciosa leaf mediated formation of silver nanoparticles [72].

Kazlagić et al. [75] prepared silver nanoparticles using apple extract. Apple fruits (100 g) were cut into small pieces and washed with a water well to remove contaminants. Then, water was added at 75 °C under stirring for an hour. Through the filtration process, apple extract is obtained in order to use as a reducing agent for silver ions. An apple extract (10 ml) is added slowly to silver nitrate solution (90 mL of 1 mol/L) under stirring, and after complete addition, the temperature is raised to 75°C, until the pale brown color is observed. The silver nanoparticle inhibited Salmonella spp and Escherichia coli growth.

The effect of the main factors in the preparation of silver nanoparticles, such as temperature and silver nitrate concentration, as well as the concentration of plant extracts in the green synthesis of plant extracts, was studied. The reaction temperature and the concentration of plant extract directly affect the formation of silver nanoparticles. The most influential is the temperature, without neglecting the other factors, as the size of the nanoparticles and the reaction rate are increased at 90 °C compared to room temperature. Also, the high concentration of plant extracts leads to an increase in the size of silver nanoparticles to speed up the reduction process of silver ions, which facilitates the growth and assembly of nanoparticles through a phenomenon called Ostwald ripping [51, 76, 77]. The chemical composition of the plant extracts controls the shape of the synthesized nanoparticles due to the different ratios of protein and reducing agents [78]. Dutta et al. [79] reported the preparation of silver nanoparticles with particle size less than 5 nm using leaf extract of S. Jambos. In this study, the phenolics moieties in the S. Jambos extracts had major contributors to reducing and stabilizing silver nanoparticles. The silver nanoparticles-S. Jambos extracts were non-toxic against HeLa and L6 cell lines.

Singh et al. [80] attempted to control the size and shape of silver nanoparticles and perform surface modification to enhance the antimicrobial activity of silver nanoparticles toward E. coli, P. aeruginosa, Kocuria, Myroides, and Promicromonospora. The tissues were ground and mixed with water under stirring for an hour. Then centrifugation was used to separate the solids from the mixture to obtain a transparent extract to prepare silver nanoparticles. The silver nanoparticles were prepared by adding tissue extract (50–400 μL) to 0.3–0.9 mM of silver nitrate at 0-80 °C, and pH ranged from 8, 10, and12. The high temperature enables the formation of silver nanoparticles within 8-10 minutes. The silver nanoparticle had 4-18 nm with spherical shapes. The authors concluded that silver nanoparticles were promising as an antibacterial against Gram-positive and Gram-negative bacteria and showed better antimicrobial efficacy than chemically made silver nanoparticles.

Prathna et al. [81]studied the effect reductant concentration, ratios of the silver salt to extract, and reaction time to optimize the bio-based synthesis of silver nanoparticles using fruits of C. Limon (lemon). TEM images showed spherical nanoparticles with a size of 25-50 nm. The reaction time of 4 h gave silver nano-spherical particles with a size below 50 nm.Bio-organic components acted as stabilizers for silver nanoparticles.

In order to identify the stability of silver-coated by bio extract, it is important to differentiate the changes

of the SPR (Surface Plasmon Resonance) peak position values with the time change during the reaction procedure or the storage period, as well as to identify the zeta potential. The zeta potential is the net surface charge of nanoparticles in the solution. The zeta potential gives information about the stability of silver nanoparticles in solutions in values of +30 mV or 30 mV. For the nanoparticles to be considered stable, the zeta potential must be either higher than +30 mV or less than -30 mV.

The zeta potential of silver nanoparticles coated with citric acid was −29 mV at pH ~ 4. This value is an indication that the silver particles are covered with negative citrate ions [81]. In another study done by Ali et al. [77], the effect of different ratios of Artemisia absinthium extract to silver nitrate was evaluated, and the study concluded that the hydrodynamic sizes of silver nanoparticles increased by increasing the concentration of the plant extract, and the ζ potential values were obtained from 32.4 to 40.4 mV. Also, the decrease in Surface Plasmon Resonance was associated with the particles' size, and that the high potential ζ values indicated more stability of the silver particles.

Organic components with plant extracts represent the main player in reducing silver ions to silver element and sometimes encapsulating them as polyphenols. Coordination bonds are formed between silver and chemical compounds that contain active oxygen, sulfur, or nitrogen atoms. For example, silver nanoparticles become negatively charged by bonding the carboxyl groups of the citrate compound, which allows electrostatic stabilization of the particles and prevents their aggregation. Along the same lines, it was observed that the protein in lemon juice causes stabilization of silver particles, indicating the chemical binding of silver nanoparticles to the functional groups of the protein. used the aqueous extract of Cinnamomum Tsoi leaves to prepare silver nanoparticles. The authors reported that the hydroxyl group of the phenol polymer reduces silver ions and does not form a complex with them. After the silver ions are reduced, the carbonyl groups of the polymer coordinate with the silver nanoparticles, and thus the polyphenols reduce the silver ions and oxidize to limit the growth of the silver particles.Maddinedi et al. [82] used the aqueous extract of Cinnamomum Tsoi leaves to prepare silver nanoparticles. The authors reported that the hydroxyl group of the polyphenol reduces silver ions and does not form a complex with silver. After the silver ions are reduced, the carbonyl groups of the polymer coordinate with the silver nanoparticles, and thus the polyphenols reduce the silver ions and oxidize to limit the growth of the silver particles. The terpenoids in chamomile extract have two actions simultaneously; a capping agent and a reducing agent, where the results proved its contact or adsorption on the surface of silver nanoparticles [83].

Table 1 presents some recent references on the use of plants in the phytosynthesis of silver nanoparticles, including the phytochemicals responsible for the reduction, stabilization and stabilization of silver nanoparticles.

Table 1. Plant-mediated fabrication of silver nanoparticles, reductant, shape, and sizes of silver nanoparticles

Reducing agents (Plant name)	Phytochemicals	Silver nanoparticles morphology		Ref.
		shape	Size (nm)	
Caesalpinia pulcherrima	Alcohol, amine, ester, carbonyl, nitro groups	Spherical	2–22	[84]
Vitis vinifera tannin fruit	tannins (with ferric chloride), flavonoids	Circle& triangle	40-60	[64]
Datura inoxia	Amine, ketone, and nitro compounds	Polygonal	15–73	[85]
Gomphrena globosa	campesterol, β-sitosterol and stigmasterol	Spherical triangle	15–25	[66]
Ipomoea digitata Linn.	Aromatic amine, amides, carbonyl, polyphenol, alcohol, and protein	spherical	~100	[86]
apple	quercetin, catechin, phloridzin, and chlorogenic acid		16	[75]
Carrot pomace	Carotenoids	Spherical	330–780	[87]
Myristicafragrans fruit	Phenols and fatty acid	Spherical	10–15	[88]
Fritillaria sp.	Hydroxyl, amine, and carbonyl groups	Spherical	5–10	[89]
Malva verticillata leaves extract	tetracontanyl palmitate and dotriacontyl tetracosanoate	Spherical	20	[90]

Conclusion

In light of the current pollution conditions that the whole world suffers from, attention is directed towards nature and reducing the use of chemicals in order to avoid their negative effects on the environment and humans. Attention is directed to obtaining nanoparticles, especially silver nanoparticles, using extracts of different plants due to the availability of these plants in various parts of the world. Besides, the extract of plants contain substances useful to humans, so plant extracts are considered economical materials compared to chemicals that perform the same role. It has been proven that many plant extracts can be used successfully in the synthesis of silver nanoparticles. Still, some of them have demonstrated antimicrobial efficiency superior to some surfactants due to the synergistic effect between plant extracts and silver nanoparticles. Mostly, spherical shapes of silver nanoparticles are formed using plant extracts, and a wide size range of sizes can be obtained, but most of these sizes are within the range of 2-80 nm. The dimensions of silver nanoparticles depend on the decoration of silver salts, the plant extract, and the temperature at which the reaction occurs. As mentioned above, green methods for the synthesis of silver nanoparticles with a size of less than 100 nm are promisingbecause the plant extracts are dual-performance. It can reduce silver ions and stabilized nanoparticles in solutions by encapsulating nanoparticles to ensure that silver particles do not accumulate as a result of the high charge of their surface. Silver nanoparticles coated with extract of several plants have been reported as good antimicrobial. Finally, some biological applications of silver nanoparticles coated with extracts and their antimicrobial, anti-oxidant, and toxicity activities are summarized.

Future prospects

There is almost stability in many international kinds of literature about the superiority of nanomaterials over large-sized materials, and there is consensus in studies and references about the power of nanotechnology in overcoming biological and environmental problems. Simply put, there is a way to prepare nanomaterials “top-down approach” such as grinding, and there is another way called “down-top approach” methods. Silver nanoparticles coated by plant extract exhibit amazing antimicrobial activity against microorganisms with much lower chances of resistance due to their novelty, as well as better safety for non-target organisms or cells. Despite the trend towards nanotechnology to find opportunities for appropriate solutions to some issues, the application of this technology faces giant challenges. For example, by following up on several studies towards the use of different plant extracts in preparing silver nanoparticles and comparing them, we find that there is a noticeable discrepancy in many of the results. Therefore, current research lacks attention to analytical methods. Extremely accurate dosimetry is another variable challenge as most scientific groups rely on mass in calculating their experimental doses, while the consideration of surface area or the number of particles in dosimetry is very accurate. Simply, nanomaterials of different sizes and constant mass have different surface areas and varying particles concentration. Therefore, dosimetry by mass correlated with surface area is very important in setting up the experimental approach, especially when assessing the toxicity of the tested nanomaterials. In addition, the wide gap in the interpretation of results based on laboratory and real-world field data is another challenge that cannot be neglected. Finally, studies that prove the compliance of silver nanoparticles prepared using plant extracts with current market regulations should be conducted, and increased investment in conducting research that determines the fate of nanoparticles after use (safe disposal of nanoparticles).

Acknowledgments

This work was supported by the Academy of Scientific Research & Technology (ASRT), Egypt, Project ID: 6896; titled “Produce new non-alcoholic antiseptics and use them effectively to clean up epidemic.” The also authors wish to thank the Egyptian petroleum research for equipment.

References

[1] M. Garside, Global nanotechnology market value 2010-2020, 2019.

[2] S. Kumar, I.B. Basumatary, H.P.K. Sudhani, V.K. Bajpai, L. Chen, S. Shukla, A. Mukherjee, Plant extract mediated silver nanoparticles and their applications as antimicrobials and in sustainable food packaging: A state-of-the-art review, Trends in Food Science & Technology, 112 (2021) 651-666.

[3] M. Khalaj, M. Kamali, M.E.V. Costa, I. Capela, Green synthesis of nanomaterials - A scientometric assessment, Journal of Cleaner Production, 267 (2020) 122036.

[4] M. Ahmed, Chapter 16 - Nanomaterial synthesis, in: R. Narain (Ed.) Polymer Science and Nanotechnology, Elsevier2020, pp. 361-399.
[5] M.S. Mostafa, L. Chen, M.S. Selim, M.A. Betiha, R. Zhang, Y. Gao, S. Zhang, G. Ge, Novel cyanate intercalated CoBi layered double hydroxide for ultimate charge separation and superior water splitting, Journal of Cleaner Production, 313 (2021) 127868.
[6] H.H. El-Maghrabi, H.R. Ali, F. Zahran, M.A. Betiha, Functionalized magnetic bentonite-iron oxide nanocomposite and its application to decrease scale formation in tubing of oil/gas production, Applied Surface Science Advances, 4 (2021) 100058.
[7] A.A. AlKahlaway, M.A. Betiha, D. Aman, A.M. Rabie, Facial synthesis of ferric molybdate (Fe2(MoO4)3) nanoparticle and its efficiency for biodiesel synthesis via oleic acid esterification, Environmental Technology & Innovation, 22 (2021) 101386.
[8] N.A. Negm, M.T.H.A. Kana, S.A. Abubshait, M.A. Betiha, Effectuality of chitosan biopolymer and its derivatives during antioxidant applications, International Journal of Biological Macromolecules, 164 (2020) 1342-1369.
[9] M.A. Betiha, Y.M. Moustafa, A.S. Mansour, E. Rafik, M.F. El-Shahat, Nontoxic polyvinylpyrrolidone-propylmethacrylate-silica nanocomposite for efficient adsorption of lead, copper, and nickel cations from contaminated wastewater, Journal of Molecular Liquids, 314 (2020) 113656.
[10] M.A. Betiha, G.G. Mohamed, N.A. Negm, M.F. Hussein, H.E. Ahmed, Fabrication of ionic liquid-cellulose-silica hydrogels with appropriate thermal stability and good salt tolerance as potential drilling fluid, Arabian Journal of Chemistry, 13 (2020) 6201-6220.
[11] M.A. Betiha, N.A. Negm, E.M. El-Sayed, M.S. Mostafa, M.F. Menoufy, Capability of synthesized sulfonated aromatic cross-linked polymer covalently bonded montmorillonite framework in productivity process of biodiesel, Journal of Cleaner Production, 261 (2020) 120995.
[12] M.A. Betiha, T. Mahmoud, A.M. Al-Sabagh, Effects of 4-vinylbenzyl trioctylphosphonium-bentonite containing poly(octadecylacrylate-co-1-vinyldodecanoate) pour point depressants on the cold flow characteristics of waxy crude oil, Fuel, 282 (2020) 118817.
[13] M.S. Mostafa, C. Lan, M.A. Betiha, R. Zhang, Y. Gaoa, G. Ge, Enhanced infrared-induced water oxidation by one-pot synthesized CoTi-Nanorods as highly infrared responsive photocatalyst, Journal of Power Sources, 464 (2020) 228176.
[14] M. Shaban, R. Hosny, A.M. Rabie, J.-J. Shim, S.A. Ahmed, M.A. Betiha, N.A. Negm, Zinc aluminate nanoparticles: Preparation, characterization and application as efficient and economic catalyst in transformation of waste cooking oil into biodiesel, Journal of Molecular Liquids, 302 (2020) 112377.
[15] H.M.A. Hassan, M.A. Betiha, E.A. El-Sharkawy, R.F.M. Elshaarawy, N.B. El-Assy, A.A. Essawy, A.M. Tolba, A.M. Rabie, Highly selective epoxidation of olefins using vanadium (IV) schiff base- amine-tagged graphene oxide composite, Colloids and Surfaces A: Physicochemical and Engineering Aspects, 591 (2020) 124520.
[16] M. Shaban, A.M. Ahmed, N. Shehata, M.A. Betiha, A.M. Rabie, Ni-doped and Ni/Cr co-doped TiO2 nanotubes for enhancement of photocatalytic degradation of methylene blue, Journal of Colloid and Interface Science, 555 (2019) 31-41.
[17] A.M. Saad, M.R. Abukhadra, S. Abdel-Kader Ahmed, A.M. Elzanaty, A.H. Mady, M.A. Betiha, J.-J. Shim, A.M. Rabie, Photocatalytic degradation of malachite green dye using chitosan supported ZnO and Ce–ZnO nano-flowers under visible light, Journal of Environmental Management, 258 (2020) 110043.
[18] A.A. Aboul-Enein, F.S. Soliman, M.A. Betiha, Co-production of hydrogen and carbon nanomaterials using NiCu/SBA15 catalysts by pyrolysis of a wax by-product: Effect of Ni–Cu loading on the catalytic activity, International Journal of Hydrogen Energy, 44 (2019) 31104-31120.
[19] Z.A. Alrowaili, I.H. Alsohaimi, M.A. Betiha, A.A. Essawy, A.A. Mousa, S.F. Alruwaili, H.M.A. Hassan, Green fabrication of silver imprinted titania / silica nanospheres as robust visible light-induced photocatalytic wastewater purification, Materials Chemistry and Physics, 241 (2020) 122403.
[20] A.S. Mansour, M.A. Betiha, Z.A. Alrowaili, S.A. Abubshait, N.A. Negm, A facile synthetic approach and optical properties of AuNPs/CdSe tetrapod and AuNPs/CdSe@rGO nanocomposites, Journal of Molecular Liquids, 293 (2019) 111493.
[21] A.M. Rabie, H.M. Abd El-Salam, M.A. Betiha, H.H. El-Maghrabi, D. Aman, Mercury removal from aqueous solution via functionalized mesoporous silica nanoparticles with the amine compound, Egyptian Journal of Petroleum, 28 (2019) 289-296.

[22] N.A. Negm, M.A. Betiha, M.S. Alhumaimess, H.M.A. Hassan, A.M. Rabie, Clean transesterification process for biodiesel production using heterogeneous polymer-heteropoly acid nanocatalyst, Journal of Cleaner Production, 238 (2019) 117854.
[23] M. Alhumaimess, O. Aldosari, H. Alshammari, M.M. Kamel, M.A. Betiha, H.M.A. Hassan, Ionic liquid green synthesis of CeO2 nanorods and nano-cubes: Investigation of the shape dependent on catalytic performance, Journal of Molecular Liquids, 279 (2019) 649-656.
[24] R.F.M. Elshaarawy, J. Dechnik, H.M.A. Hassan, D. Dietrich, M.A. Betiha, S. Schmidt, C. Janiak, Novel high throughput mixed matrix membranes embracing poly ionic liquid-grafted biopolymer: Fabrication, characterization, permeation and antifouling performance, Journal of Molecular Liquids, 266 (2018) 484-494.
[25] A.M. Elfadly, A.M. Badawi, F.Z. Yehia, Y.A. Mohamed, M.A. Betiha, A.M. Rabie, Selective nano alumina supported vanadium oxide catalysts for oxidative dehydrogenation of ethylbenzene to styrene using CO2 as soft oxidant, Egyptian Journal of Petroleum, 22 (2013) 373-380.
[26] M.S. Abdel Salam, M.A. Betiha, S.A. Shaban, A.M. Elsabagh, R.M. Abd El-Aal, F.Y. El kady, Synthesis and characterization of MCM-41-supported nano zirconia catalysts, Egyptian Journal of Petroleum, 24 (2015) 49-57.
[27] T. Mahmoud, M.A. Betiha, Poly(octadecyl acrylate-co-vinyl neodecanoate)/Oleic Acid-Modified Nano-graphene Oxide as a Pour Point Depressant and an Enhancer of Waxy Oil Transportation, Energy & Fuels, 35 (2021) 6101-6112.
[28] M.A. Betiha, A.E. ElMetwally, A.M. Al-Sabagh, T. Mahmoud, Catalytic Aquathermolysis for Altering the Rheology of Asphaltic Crude Oil Using Ionic Liquid Modified Magnetic MWCNT, Energy & Fuels, 34 (2020) 11353-11364.
[29] A.M. Al-Sabagh, M.A. Betiha, D.I. Osman, A.I. Hashim, M.M. El-Sukkary, T. Mahmoud, Preparation and Evaluation of Poly(methyl methacrylate)-Graphene Oxide Nanohybrid Polymers as Pour Point Depressants and Flow Improvers for Waxy Crude Oil, Energy & Fuels, 30 (2016) 7610-7621.
[30] A.A. Abd El Khalk, M.A. Betiha, A.S. Mansour, M.G. Abd El Wahed, A.M. Al-Sabagh, High Degradation of Methylene Blue Using a New Nanocomposite Based on Zeolitic Imidazolate Framework-8, ACS Omega, (2021).
[31] Z.M.H. Kheiralla, A.A. Rushdy, M.A. Betiha, N.A.N. Yakob, High-performance antibacterial of montmorillonite decorated with silver nanoparticles using microwave-assisted method, Journal of Nanoparticle Research, 16 (2014) 2560.
[32] O.V. Kharissova, H.V.R. Dias, B.I. Kharisov, B.O. Pérez, V.M.J. Pérez, The greener synthesis of nanoparticles, Trends in Biotechnology, 31 (2013) 240-248.
[33] J. Huang, L. Lin, D. Sun, H. Chen, D. Yang, Q. Li, Bio-inspired synthesis of metal nanomaterials and applications, Chemical Society Reviews, 44 (2015) 6330-6374.
[34] C.V. Restrepo, C.C. Villa, Synthesis of silver nanoparticles, influence of capping agents, and dependence on size and shape: A review, Environmental Nanotechnology, Monitoring & Management, 15 (2021) 100428.
[35] R. Kalaivani, M. Maruthupandy, T. Muneeswaran, A. Hameedha Beevi, M. Anand, C.M. Ramakritinan, A.K. Kumaraguru, Synthesis of chitosan mediated silver nanoparticles (Ag NPs) for potential antimicrobial applications, Frontiers in Laboratory Medicine, 2 (2018) 30-35.
[36] H.E. Emam, H.B. Ahmed, R.M. Abdelhameed, Melt intercalation technique for synthesis of hetero-metallic@chitin bio-composite as recyclable catalyst for prothiofos hydrolysis, Carbohydrate Polymers, 266 (2021) 118163.
[37] H.B. Ahmed, N. Saad, H.E. Emam, Recyclable palladium based nano-catalytic laborer encaged within bio-granules for dye degradation, Surfaces and Interfaces, 25 (2021) 101175.
[38] H.B. Ahmed, H.E. Emam, Seeded growth core-shell (Ag–Au–Pd) ternary nanostructure at room temperature for potential water treatment, Polymer Testing, 89 (2020) 106720.
[39] H.E. Emam, N.M. Saad, A.E.M. Abdallah, H.B. Ahmed, Acacia gum versus pectin in fabrication of catalytically active palladium nanoparticles for dye discoloration, International Journal of Biological Macromolecules, 156 (2020) 829-840.
[40] N.S.E. Ahmed, Color Data and Antibacterial Properties of Smart Ag/polypyrrole- Nanocoated Cotton Fabric, Egyptian Journal of Chemistry, 63 (2020) 3547-3555.
[41] M.A. El-Sheikh, A. Al-Enezy, F. El-Enezy, D. Ashammri, F. El-Enezy, W. Alrowili, A Novel Method for The Preparation of Conductive Methyl Cellulose-Silver Nanoparticles-Polyaniline-Nanocomposite, Egyptian Journal of Chemistry, 63 (2020) 3567-3582.

[42] t. husien, a. aboelnaga, Synthesis, Characterization, and Biological Applications of New Series of Azo Triazole Organometallic Derivatives and Their Silver Nanoparticle Forms, Egyptian Journal of Chemistry, 63 (2020) 101-115.
[43] I.O. Ali, M. El-Molla, Synthesis of Zinc oxide and Silver/ Zinc oxide Nanocomposite for Production of Antimicrobial Textiles, Egyptian Journal of Chemistry, 62 (2019) 797-817.
[44] B.J. Wiley, S.H. Im, Z.-Y. Li, J. McLellan, A. Siekkinen, Y. Xia, Maneuvering the surface plasmon resonance of silver nanostructures through shape-controlled synthesis, ACS Publications, 2006.
[45] S.M. Abd Elhaleem, F. Elsebaei, S. Shalan, F. Belal, Utilization of Localized Surface Plasmon Resonance of Silver Nanoparticles for the Spectrofluorimetric Estimation of Oxymetazoline in Dosage Forms: Application to Aqueous Humor, Journal of Fluorescence, (2021) 1-11.
[46] C.-L. Huang, H.J. Huang, S.-H. Chen, Y.-S. Huang, P.-C. Kao, Y.-F.C. Chau, H.-P. Chiang, Localized surface plasmon resonance enhanced by the light-scattering property of silver nanoparticles for improved luminescence of polymer light-emitting diodes, Journal of Industrial and Engineering Chemistry, 103 (2021) 283-291.
[47] H.T. Phan, A.J. Haes, What Does Nanoparticle Stability Mean?, The Journal of Physical Chemistry C, 123 (2019) 16495-16507.
[48] A. Hebeish, T.I. Shaheen, M.E. El-Naggar, Solid state synthesis of starch-capped silver nanoparticles, International Journal of Biological Macromolecules, 87 (2016) 70-76.
[49] C.-C. Li, S.-J. Chang, F.-J. Su, S.-W. Lin, Y.-C. Chou, Effects of capping agents on the dispersion of silver nanoparticles, Colloids and Surfaces A: Physicochemical and Engineering Aspects, 419 (2013) 209-215.
[50] S.S. Zaki, Z.H. Kheiralla, A.A. Rushdy, M.A. Betiha, H.B. Abousittash, Embedded Mesoporous Silica Silver Nanoparticles as potential antibacterial agent againstMultidrug-Resistant Bacteria, Journal of Scientific Research in Science, 34 (2017) 158-178.
[51] R. Sithara, P. Selvakumar, C. Arun, S. Anandan, P. Sivashanmugam, Economical synthesis of silver nanoparticles using leaf extract of Acalypha hispida and its application in the detection of Mn(II) ions, Journal of Advanced Research, 8 (2017) 561-568.
[52] T.S. Alomar, N. AlMasoud, M.A. Awad, M.F. El-Tohamy, D.A. Soliman, An eco-friendly plant-mediated synthesis of silver nanoparticles: Characterization, pharmaceutical and biomedical applications, Materials Chemistry and Physics, 249 (2020) 123007.
[53] S. Valsalam, P. Agastian, G.A. Esmail, A.-K.M. Ghilan, N.A. Al-Dhabi, M.V. Arasu, Biosynthesis of silver and gold nanoparticles using Musa acuminata colla flower and its pharmaceutical activity against bacteria and anticancer efficacy, Journal of Photochemistry and Photobiology B: Biology, 201 (2019) 111670.
[54] M.R. Bindhu, M. Umadevi, G.A. Esmail, N.A. Al-Dhabi, M.V. Arasu, Green synthesis and characterization of silver nanoparticles from Moringa oleifera flower and assessment of antimicrobial and sensing properties, Journal of Photochemistry and Photobiology B: Biology, 205 (2020) 111836.
[55] S. Raja, V. Ramesh, V. Thivaharan, Green biosynthesis of silver nanoparticles using Calliandra haematocephala leaf extract, their antibacterial activity and hydrogen peroxide sensing capability, Arabian Journal of Chemistry, 10 (2017) 253-261.
[56] G.M. Nazeruddin, N.R. Prasad, S.R. Waghmare, K.M. Garadkar, I.S. Mulla, Extracellular biosynthesis of silver nanoparticle using Azadirachta indica leaf extract and its anti-microbial activity, Journal of Alloys and Compounds, 583 (2014) 272-277.
[57] M. Jha, N.G. Shimpi, Spherical nanosilver: Bio-inspired green synthesis, characterizations, and catalytic applications, Nano-Structures & Nano-Objects, 16 (2018) 234-249.
[58] B. Kumar, K. Smita, A. Debut, L. Cumbal, Extracellular green synthesis of silver nanoparticles using Amazonian fruit Araza (Eugenia stipitata McVaugh), Transactions of Nonferrous Metals Society of China, 26 (2016) 2363-2371.
[59] L.J. Lizcano, F. Bakkali, M. Begoña Ruiz-Larrea, J. Ignacio Ruiz-Sanz, Antioxidant activity and polyphenol content of aqueous extracts from Colombian Amazonian plants with medicinal use, Food Chemistry, 119 (2010) 1566-1570.
[60] M.S. Hernández, O. Martínez, J.P. Fernández-Trujillo, Behavior of arazá (Eugenia stipitata Mc Vaugh) fruit quality traits during growth, development and ripening, Scientia Horticulturae, 111 (2007) 220-227.
[61] S. Bhakya, S. Muthukrishnan, M. Sukumaran, M. Grijalva, L. Cumbal, J.H. Franklin Benjamin, T. Senthil Kumar, M.V. Rao, Antimicrobial,

antioxidant and anticancer activity of biogenic silver nanoparticles – an experimental report, RSC Advances, 6 (2016) 81436-81446.
[62] S. Ahmed, Saifullah, M. Ahmad, B.L. Swami, S. Ikram, Green synthesis of silver nanoparticles using Azadirachta indica aqueous leaf extract, Journal of Radiation Research and Applied Sciences, 9 (2016) 1-7.
[63] M.I. Alkhalaf, R.H. Hussein, A. Hamza, Green synthesis of silver nanoparticles by Nigella sativa extract alleviates diabetic neuropathy through anti-inflammatory and antioxidant effects, Saudi Journal of Biological Sciences, 27 (2020) 2410-2419.
[64] N. Hashim, M. Paramasivam, J.S. Tan, D. Kernain, M.H. Hussin, N. Brosse, F. Gambier, P.B. Raja, Green mode synthesis of silver nanoparticles using Vitis vinifera's tannin and screening its antimicrobial activity / apoptotic potential versus cancer cells, Materials Today Communications, 25 (2020) 101511.
[65] G.N. Maity, P. Maity, I. Choudhuri, G.C. Sahoo, N. Maity, K. Ghosh, N. Bhattacharyya, S. Dalai, S. Mondal, Green synthesis, characterization, antimicrobial and cytotoxic effect of silver nanoparticles using arabinoxylan isolated from Kalmegh, International Journal of Biological Macromolecules, 162 (2020) 1025-1034.
[66] P. Tamilarasi, P. Meena, Green synthesis of silver nanoparticles (Ag NPs) using Gomphrena globosa (Globe amaranth) leaf extract and their characterization, Materials Today: Proceedings, 33 (2020) 2209-2216.
[67] S.S. Mansouri, S. Ghader, Experimental study on effect of different parameters on size and shape of triangular silver nanoparticles prepared by a simple and rapid method in aqueous solution, Arabian Journal of Chemistry, 2 (2009) 47-53.
[68] P. Devaraj, P. Kumari, C. Aarti, A. Renganathan, Synthesis and Characterization of Silver Nanoparticles Using Cannonball Leaves and Their Cytotoxic Activity against MCF-7 Cell Line, Journal of Nanotechnology, 2013 (2013) 598328.
[69] J. Baharara, F. Namvar, T. Ramezani, N. Hosseini, R. Mohamad, Green Synthesis of Silver Nanoparticles using Achillea biebersteinii Flower Extract and Its Anti-Angiogenic Properties in the Rat Aortic Ring Model, Molecules, 19 (2014).
[70] V.K.M. Katta, R.S. Dubey, Green synthesis of silver nanoparticles using Tagetes erecta plant and investigation of their structural, optical, chemical and morphological properties, Materials Today: Proceedings, 45 (2021) 794-798.
[71] V. Ravichandran, S. Vasanthi, S. Shalini, S.A.A. Shah, M. Tripathy, N. Paliwal, Green synthesis, characterization, antibacterial, antioxidant and photocatalytic activity of Parkia speciosa leaves extract mediated silver nanoparticles, Results in Physics, 15 (2019) 102565.
[72] F. Jamaluddin, S. Mohameda, M.N. Lajis, Hypoglycaemic effect of Stigmast-4-en-3-one, from Parkia speciosa empty pods, Food Chemistry, 54 (1995) 9-13.
[73] E. Bulut, M. Özacar, Rapid, Facile Synthesis of Silver Nanostructure Using Hydrolyzable Tannin, Industrial & Engineering Chemistry Research, 48 (2009) 5686-5690.
[74] R. Bhat, V.G. Sharanabasava, R. Deshpande, U. Shetti, G. Sanjeev, A. Venkataraman, Photo-bio-synthesis of irregular shaped functionalized gold nanoparticles using edible mushroom Pleurotus florida and its anticancer evaluation, Journal of Photochemistry and Photobiology B: Biology, 125 (2013) 63-69.
[75] A. Kazlagić, O.A. Abud, M. Ćibo, S. Hamidović, B. Borovac, E. Omanović-Mikličanin, Green synthesis of silver nanoparticles using apple extract and its antimicrobial properties, Health and Technology, 10 (2020) 147-150.
[76] M.R. Shaik, M. Khan, M. Kuniyil, A. Al-Warthan, H.Z. Alkhathlan, M.R.H. Siddiqui, J.P. Shaik, A. Ahamed, A. Mahmood, M. Khan, S.F. Adil, Plant-Extract-Assisted Green Synthesis of Silver Nanoparticles Using Origanum vulgare L. Extract and Their Microbicidal Activities, Sustainability, 10 (2018).
[77] M. Ali, B. Kim, K. D. Belfield, D. Norman, M. Brennan, G.S. Ali, Green synthesis and characterization of silver nanoparticles using Artemisia absinthium aqueous extract — A comprehensive study, Materials Science and Engineering: C, 58 (2016) 359-365.
[78] P. Malik, R. Shankar, V. Malik, N. Sharma, T.K. Mukherjee, Green chemistry based benign routes for nanoparticle synthesis, Journal of Nanoparticles, 2014 (2014).
[79] P.P. Dutta, M. Bordoloi, K. Gogoi, S. Roy, B. Narzary, D.R. Bhattacharyya, P.K. Mohapatra, B. Mazumder, Antimalarial silver and gold nanoparticles: Green synthesis, characterization and in vitro study, Biomedicine & Pharmacotherapy, 91 (2017) 567-580.
[80] A. Singh, B. Sharma, R. Deswal, Green silver nanoparticles from novel Brassicaceae cultivars with enhanced antimicrobial potential than earlier reported Brassicaceae members, Journal of Trace

Elements in Medicine and Biology, 47 (2018) 1-11.
[81] T.C. Prathna, N. Chandrasekaran, A.M. Raichur, A. Mukherjee, Biomimetic synthesis of silver nanoparticles by Citrus limon (lemon) aqueous extract and theoretical prediction of particle size, Colloids and Surfaces B: Biointerfaces, 82 (2011) 152-159.
[82] S.b. Maddinedi, B.K. Mandal, S.K. Maddili, Biofabrication of size controllable silver nanoparticles – A green approach, Journal of Photochemistry and Photobiology B: Biology, 167 (2017) 236-241.
[83] M. Parlinska-Wojtan, M. Kus-Liskiewicz, J. Depciuch, O. Sadik, Green synthesis and antibacterial effects of aqueous colloidal solutions of silver nanoparticles using camomile terpenoids as a combined reducing and capping agent, Bioprocess and Biosystems Engineering, 39 (2016) 1213-1223.
[84] P. Moteriya, S. Chanda, Synthesis and characterization of silver nanoparticles using Caesalpinia pulcherrima flower extract and assessment of their in vitro antimicrobial, antioxidant, cytotoxic, and genotoxic activities, Artificial Cells, Nanomedicine, and Biotechnology, 45 (2017) 1556-1567.
[85] B. Gajendran, P. Durai, K.M. Varier, W. Liu, Y. Li, S. Rajendran, R. Nagarathnam, A. Chinnasamy, Green Synthesis of Silver Nanoparticle from Datura inoxia Flower Extract and Its Cytotoxic Activity, BioNanoScience, 9 (2019) 564-572.
[86] T. Varadavenkatesan, R. Selvaraj, R. Vinayagam, Dye degradation and antibacterial activity of green synthesized silver nanoparticles using Ipomoea digitata Linn. flower extract, International Journal of Environmental Science and Technology, 16 (2019) 2395-2404.
[87] J. Cieśla, M. Chylińska, A. Zdunek, M. Szymańska-Chargot, Effect of different conditions of synthesis on properties of silver nanoparticles stabilized by nanocellulose from carrot pomace, Carbohydrate Polymers, 245 (2020) 116513.
[88] D. Sasidharan, T.R. Namitha, S.P. Johnson, V. Jose, P. Mathew, Synthesis of silver and copper oxide nanoparticles using Myristica fragrans fruit extract: Antimicrobial and catalytic applications, Sustainable Chemistry and Pharmacy, 16 (2020) 100255.
[89] S. Hemmati, M.M. Heravi, B. Karmakar, H. Veisi, Green fabrication of reduced graphene oxide decorated with Ag nanoparticles (rGO/Ag NPs) nanocomposite: A reusable catalyst for the degradation of environmental pollutants in aqueous medium, Journal of Molecular Liquids, 319 (2020) 114302.
[90] I. Sk, M.A. Khan, A. Haque, S. Ghosh, D. Roy, S. Homechuadhuri, M.A. Alam, Synthesis of gold and silver nanoparticles using Malva verticillata leaves extract: Study of gold nanoparticles catalysed reduction of nitro-Schiff bases and antibacterial activities of silver nanoparticles, Current Research in Green and Sustainable Chemistry, 3 (2020) 100006.