CHAPTER

Plant and agri-waste-mediated synthesis of metal nanoparticles

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1 Introduction

In recent years, research interest in metal nanoparticles and their synthesis has increased significantly because of their intensive applications in different industrial sectors (Das and Chatterjee, 2019). Nanoparticles are being investigated to the fundamental building blocks of nanotechnology. Nanotechnology branch is interdisciplinary, which mentioned to the subdivision of science and engineering, with a range of technical characteristics, including manufacture, characterization, nanoscale structure and material handling. Nanoscience is the study of phenomena, at 1–100 nm particle size and nanoparticles are particulate dispersion of solid particles with at least one dimension less than 100 nm (Khan et al., 2019a). Nanoparticles have opened on various fronts for the design of new materials and assessment of their properties by regulating size, morphology and distribution of particles (Albanese et al., 2012). Metal nanoparticles do not consider in metal–metal chemical bond and determined as isolated particle between 1 and 100 nm sizes. Metal nanoparticles consist different extraordinary characteristics as compared to their bulk metal that generally contains a degenerated density of energy state, and a high ratio of surface to volume, increasing their contact with other molecules (Moghadam et al., 2019; Maghsoodi et al., 2019). Therefore, shows extensive applications in the various emerging fields, such as medicine, pharmacy, food technology, agriculture, and environmental science (Vishwakarma et al., 2017; Tazwar and Devra, 2020).

For the synthesis of metal nanoparticles, different protocols have been developed. Two key strategies are commonly used to synthesize particles, referred to top-down, and bottom-up approach (Ahmed et al., 2016). In the top-down approach, the bulk material is broken down into small particles by size reduction using physical and chemical techniques, such as grinding, milling, and chemical reduction, etc. (Shedbalkar et al., 2014). The physical approaches require a high amount of energy, which makes these processes more capital intensive. However, chemical methods are eco-toxic because of the use of various hazardous chemicals, which are responsible for carcinogenicity or genotoxicity and cytotoxicity (Kharisov et al., 2016).

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Whereas nanoparticles are synthesized by self-assembly of atoms into nuclei in the bottom-up method, which further develop into nano-sized particles. This approach included a chemical and biological method for the production of nanoparticles. The most successful method for the synthesis of nanoparticles, however, is the bottom-up approach, where a nanoparticle is formed from simpler molecules recognized as precursors of reactions. In this way, the size and shape of nanoparticles can be regulated by variations in precursor concentrations and reaction conditions such as pH temperature, etc., depending on the consecutive applications (Virkutyte and Varma, 2013). Researcher, constant efforts to develop a green process for the synthesis of nanoparticles that is simple, efficient and genuine. In order to synthesize stable and well-defined functionalized nanoparticles, several species serve as safe, eco-friendly and green precursors (Singh et al., 2019). Thus, it is important to explore the synthesis of nanoparticles in a more authentic and feasible process. In the production of nanoparticles, topics of concern are economically relevant, eco-friendly, and socially appropriate, as well as the accessibility of local properties. In order to keep the prices of competing nanotechnology-based goods economical for the purchaser, companies must maintain complex system stability and sustainability between environmentally green methods and methods. Without the presence of harmful chemicals, the green technology-based synthesis method works under green conditions.

The green synthesis includes biological resources like plant extract and biodegradable waste as a reducing agent. In terms of eco-friendly alternatives, this method is beneficial for toxic chemicals that can be processed in comparatively less time, feasible, and can provide immense applications. Moreover, because plant components act as a stabilizing agent, there is no need to stabilize agents (Makarov et al., 2014). Abundant pharmacological metabolites are available and set up to bind to the synthesized nanoparticles, providing additional benefit through the increased efficacy of the nanoparticles (Singh et al., 2016). Coincidentally, the ever-growing amount of agri-waste resulting from agricultural and horticultural activities has also caused significant concern in recent years (Sharma et al., 2019). Researchers started researching waste valorization techniques for turning agri-waste into value-added goods as an eco-friendly alternative to traditional methods of disposal such as composting, incineration, and landfill to solve this ever-increasing issue. An attractive sustainable source of biomolecules and bioactive compounds that can be used by the chemical and pharmaceutical industries to manufacture high-value products such as metal nanoparticles are produced by plant-based agri-waste. Therefore, the synthesis of biogenic metal nanoparticles is considered a very interesting alternative to greener and more eco-friendly processing due to the use of chemicals lower toxicity and the use of ambient and pressure temperatures in the synthesis (Chhipa, 2019). The next section highlights the different green approaches used to synthesize metal nanoparticles that, as a green chemistry term, are successful and retain their biological properties. This is accompanied by a review of the different factors influencing the metal nanoparticles' synthesis rate.

2 Synthesis from plant materials

In nanotechnology, plant-mediated synthesis of metal nanoparticles has been considered as an eco-friendly process. Biological synthesis, pathways of molecular tolerance, and metabolic processes for the synthesis of nanoparticles (Rai et al., 2018). Plants have a high inclination to synthesize nanoparticles as it is renewable, biodegradable, and it provides a natural stabilizing agent to the nanoparticles immediately. According to Yallappa et al. (2015), the simplest cost-effective and reproducible method is green synthesis of metallic nanoparticles by various plants, parts. Higher antioxidants found in photochemical constituents in seeds, fruits, leaves, and stems are blocked by various herbs and plant sources. Therefore, in the synthesis and development of nanoparticles, the benefit of plant-based phytochemicals provides a significant symbiosis between natural science and nanotechnology. This relation gives nanotechnology, introduced as green nanotechnology, a characteristically green approach. These manufacturing processes can be carried out without substantial environmental emissions, thereby setting new standards for clean and green technologies that are highly sustainable and economically viable (Zambre et al., 2013).

For the synthesis of metal and metal oxide nanoparticles, extracts from various parts of the plants, including leaf, root, latex, fruit, seed, and stem, were used. Bioactive polyphenol proteins, phenolic acids, alkaloids, carbohydrates, terpenoids, etc. are plant extracts that play an important role in reducing and then stabilizing metallic ions (Schrofel et al., 2014). The key factor in the different size and shape of the synthesized nanoparticles is presumed to be the concentration and confirmation of these active molecules among different plants and their parts with metal ion (Njagi et al., 2010). An ambient atmospheric action is the synthesis of nanoparticles by metal salt reduction by plant extract. The plant extract and metal salt solution are well combined at room temperature (Park et al., 2011). The biochemical reduction in salt instants begins and the formation of nanoparticles is demonstrated by a change in the color of the reaction solution (Fig. 1).

The synthesis of green nanoparticles supported by plants can be split into three stages: activation, growth and termination (Kim et al., 2010). Metal ions are recovered from their salt solution in the activation step by the reaction of plant metabolites. The metal ions move from the state of mono or divalent oxidation to zero-valent states, then a metal atom is nucleated (Malik et al., 2014). This is followed by the growth stage; nanoparticle collects to form and different morphologies like cubic, spherical, triangle, rods and wires (Akhtar et al., 2013). In the last termination stages, the nanoparticle gets their stable morphology when capped by plant biomolecules (Fig. 2).

2.1 Leaf extract

The green synthesis of metallic nanoparticles using different plant leaf extracts has been documented by many researchers. Nilavukkarasi et al. (2020) reported that the biosynthesized silver nanoparticles from *C. zeylanica* leaf extract have

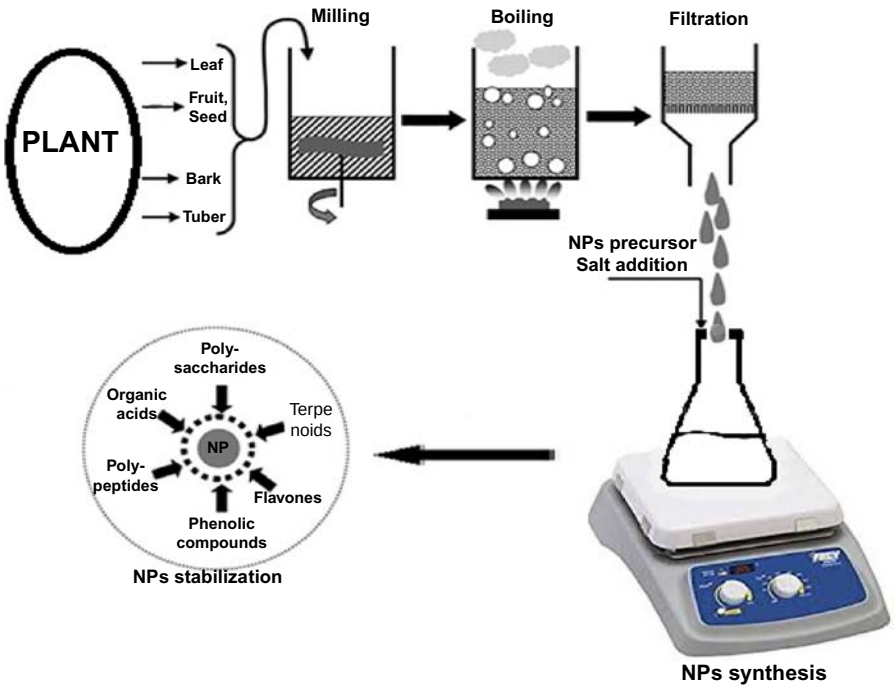

FIG. 1

Graphical representation of synthesis of metal/metal oxide nanoparticles using plant extract.

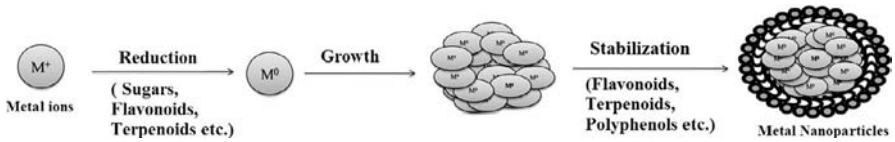

FIG. 2

Activation, growth and stabilization of plant mediated nanoparticles.

admirable antimicrobial activity against pathogenic microorganisms and cytotoxicity studies have excellent anti proliferative properties. Biosynthesized AgNPs have Crystalline, The FT-IR spectrum confirmed that uniform, spherical, and monodispersed nanoparticles with a mean size of 23 nm, and the functional groups present in the AgNPs. Machado et al. (2013) analyzed the feasibility of several tree leaves for generating iron nanoparticles. The antioxidant potential of leaf extract was also assessed. The findings indicate that extracts with a higher antioxidant potential than non-dried leaves derive from dried leaves. The richest extracts were

produced from oak pomegranate and green tea, and the results of TEM analysis verified the iron nanoparticles (diameter 10 to 20 nm) could be synthesized using these plant extracts. The cheapest and greenest process for the synthesis of nanoparticles is known to be water used as a solvent for leaf extract preparation. The maximum absorption peak in UV used a low-cost reductant for the synthesis of AgNPs by *Azardirachta indica* (Neem) leaf extract in another study by Nagar and Devra (2019). Visible spectroscopy of synthesized AgNPs was found at 433 nm. In the oxidative degradation of acid orange 10 (AO10) and acid orange 52 (AO52) by advanced oxidation in an aqueous medium, synthesized AgNPs showed excellent catalytic activity. Joghee et al. (2019) reported eco-friendly and cost-effective biosynthesis of ZnO and MgO NPs were obtained from the leaf extract of *Pisonia grandis* R.Br. GCMS analysis reveals 50 phytochemicals were present in the plant extract. In stabilizing details on zinc and magnesium nanoparticles, biological molecules containing phenolic compounds present in an extract play an essential role confirmed by FTIR studies. XRD analysis indicates that ZnO particles were hexagonal phase and MgO particles as face-centered cubic geometry, with a diameter in the range, 30–60 nm, and 60–80 nm, respectively. Patil et al. (2016) examined the use of *Limonia acidissima* leaves to synthesize ZnO NPs and to test their effectiveness against the growth of *Mycobacterium tuberculosis*. The UV.Visible data show that the formation of ZnO NPs is confirmed by an absorbance peak at 374 nm, and are spherical with a size between 12 and 53 nm. Agarwal et al. (2017) reported phyto-assisted synthesis of ZnO NPs using leaf broth of *Cassia alata*, and Zinc acetate (0.01 M) in another study. The formation of ZnO NPs by UV. Visible spectra, suggested the presence of a strong peak at 320 nm, confirming the nanoparticles synthesis. SEM micrographs illustrate the presence of spherical nanoparticles with size range 60–80 nm.

Furthermore, FTIR spectra indicated the peak at 476.42 cm^{-1} corresponding to the stretching vibrations of ZnO-Zn, characteristic peak at ZnO NPs. By using $Ni(NO_3)2.6H2O$ as a precursor and a leaf extract of *Ocimum sanctum as* a reducing and stabilizing agent, Pandian et al. (2015) synthesized NiNPs. The NiNPs formation was confirmed by the peak of visible spectra at 395 nm corresponding to NiNPs. XRD results confirm NiNPs have face-cantered cubic structure and average size 30 nm, which are good agreement with SEM and TEM results. To research further, in the biosynthesis of TiO_2 NPs, Thakur et al. (2019) reported characterization results revealed that transmission electron microscopy images showed the synthesized particles were spherical in shape and size ranged from 15 to 50 nm. They also studied the function of TiO_2 exhibited broad spectrum antimicrobial activity against vast range of pathogens.

In addition, the *O. sanctum* (Tulsi) leaf extract was used as a reduction agent for the synthesis of PtNPs at a temperature of 100°C.The average size of the PtNPs was 23 nm (Soundarrajan et al., 2012). Some other recent studies are reported for the biosynthesis of metal/metal oxide nanoparticles by plant leaves are includes in Table 1.

Table 1 Metal/metal oxide nanoparticles biosynthesized by leaves and fruit extract as plant parts.

Biogenic agent	Green NPs	Size (nm) and shape	Applications	References
Leaves extract				
Capparis zeylanica	AgNPs	23 nm, Spherical	Antimicrobial and antiproliferation activities	Nilavukkarasi et al. (2020)
Oak, pomegranate, green tea	FeNPs	10–20 nm	Antioxidant	Machado et al. (2013)
A. indica	CuNPs	48 nm, Cubical	For degradation of dye Orange G	Nagar and Devra (2018a)
Pisonia grandis R.Br.	ZnO MgO	30–60 nm, Hexagonal 60–80 nm, cubical		Joghee et al. (2019)
C. alata	ZnO NPs	60–80 nm, Spherical	Antibacterial against ***E.coli***	Agarwal et al. (2017)
Limonia acidissima	ZnO NPs	12–53 nm, Spherical	Antibacterial against M***ycobacterium tuberculosis***	Patil et al. (2016)
O. sanctum	NiNPs	30 nm, FCC Crystal	Adsorption of dye and pollutant	Pandian et al. (2015)
A. indica	TiO2 NPs	124 nm, Spherical	Photocatalyst for environmental remediation	Shankar et al. (2003)
		15–50 nm, Spherical	Antibacterial agent	Thakur et al. (2019)
A. indica	AgNPs	9 nm, Spherical	Catalyst for textile dyes degradation	Nagar and Devra (2019)
O. sanctum	PtNPs	23 nm, Irregular	Water electrolysis application	Soundarrajan et al. (2012)
Bauhinia purpurea	AgNPs, AuNPs	Spherical, hexagonal	Anticancer, antimicrobial, antioxidant and catalytic activities	Vijayan et al. (2019)
Olea europaea	CuNPs	20–50 nm, Spherical	Anticancer agent	Sulaiman et al. (2018)
Nigella arvensis	AuNPs	3–37 nm, Spherical	Antibacterial and antioxidant	Chahardoli et al. (2018)
Piper beetle	AgNPs	6–14 nm, Spherical	Plant fungal pathogen controller	Khan et al. (2019a,b)
Tomato	AgNPs	< 87 nm, Polydisperse	Reduce the yield losses caused by bacterial wilt	Santiago et al. (2019)
Sasa borealis	AuNPs	10–30 nm, Oval spherical	Anticancer agent	Patil et al. (2018)
Tropaeolum majus	AgNPs	35–55 nm, FCC	Antibacterial, antifungal, antioxidant and anticancer agent	Valsalam et al. (2019)
A. indica	FeNPs		Catalyst for textile dyes degradation	Devra and Rathore (2020)
Passiflora edulis	AgNPs	3–7 nm, Spherical	Antioxidant and photocatalytic	Thomas et al. (2019)

Berberis vulgaris	AgNPs	30–70 nm, Spherical	Antibacterial agent	Behravan et al. (2019)
Green tea	AuNPs	8.53 ± 1.7 nm, sphere, rod, star	Therapeutic applications as drug delivery vehicles	Lee et al. (2019)
Psidium guajava	CuO NPs	2–6 nm, Spherical	Photocatalytic degradation of dyes	Singh et al. (2019)
Falcaria vulgaris	CuO NPs	20-25 nm	Antioxidant, antifungal, antibacterial, and cutaneous wound healing potentials without any cytotoxicity	Zangeneh et al. (2019)
Cissus arnotiana	CuO NPs	60–90 nm, Spherical	Antibacterial and antioxidant activities	Rajeshkumar et al. (2019)
Eucalyptus globulus	CuO NPs	16.7–22.5 nm	Effective antibacterial and antibiofilm agent	Ali et al. (2019)
Salvia miltiorrhiza	AgNPs	12–80 nm, Spherical, oval, hexagonal, triangular	Anticancer potential in human prostate cancer	Zhang et al. (2019)
Achillea millefolium	CuO NPs	28 nm, Semispherical	Biomedical applications	Rabiee et al. (2020a,b)
Rosmarinus officinalis	PdNPs	15–90 nm, Semispherical	Antibacterial, antifungal and catalytic applications	Rabiee et al. (2020a,b)
Plukenetia volubilis L.	Cu2O	6–10 nm, Spherical	Nanocatalyst for degradation of organic pollutants in water	Kumar et al. (2020)
Ageratum houstonianum	CuNPs	Approximate 80 nm, different shapes	Photocatalytic and antibacterial	Chanraker et al. (2020)
Fruit extract				
Terminalia chebula	PdNPs, FeNPs	FeNPs > 80 nm, Amorphous; PdNPs > 100 nm Cubical	Antireducing agent	Mohan Kumar et al. (2013)
Passiflora tripartita var. *mollissima*	Fe_3O_4 NPs	22.3 ± 3 nm, Spherical	Synthesis of biological important 2-arylbenzimidazoles	Kumar et al. (2014a,b)
H. dulcis	AuNPs	15–20 nm	Biomedical application	Basavegowda et al. (2014)
C. maxima	AuNPs	25.7 ± 10 nm	Catalytic activity for 4-nitrophenol reduction to 4-aminophenol reduction	Yu et al. (2016)
P. longum	AuNPs	56 nm, Spherical	Antioxidant and catalytic agent	Nakkala et al. (2016)
Dhruva serrulata	AgNPs, AuNPs	66 nm Spherical, 65 nm, Hexagonal	Biomedical and environmental applications	Singh et al. (2018)
Chaenomeles sinensis	AgNPs, AuNPs	5–20 nm, 20–40 nm	Biomedical applications	Oh et al. (2018)
Phyllanthus emblica	AgNPs	30 nm, Hexagonal	Antimicrobial applications	Renuka et al. (2020)
P. farcta	AgNPs	12.68 nm	Biomedical applications	Salari et al. (2019)
Comus mas	AgNPs, AuNPs	16 nm, spherical, 19 nm, pseudo spherical	Mobilized the antioxidant defense mechanisms	Filip et al. (2019)

2.2 Fruit extract

In Table 1, some scientists use fruit for the synthesis of metallic nanoparticles. Kumar et al. (2013), using the fruit extract of *Terminates chebula*, formed palladium and iron nanoparticles. Polyphenolic-rich *T. chebula* extract displays a redox potential of 0.63 V vs. saturated calomel electrode by cyclic voltammetry, which helps to minimize iron salt to iron nanoparticles. Highly stable FeNPs were developed by *T. chebula* extract, which requires polyphenol complexation, by reducing the ferrous salt solution. A 5:1 ratio of fruit extract to $FeSO_4.7H_2O$ solution, then centrifugally separated solid substance, was reacted. Analysis of X-ray diffraction (XRD) and transmission electron microscope (TEM) indicates that amorphous FeNPs were less than 80 nm in scale. Fe_3O_4 NPs were synthesized by *Passiflora tripartita* var. *mollissima* fruit extract and applied as a catalyst at room temperature for the synthesis of 2-arylbenzimideazole. *P. tripartita* var. aqueous extract Mollissima reacts with iron salt solution, synthesizes spherical FeO NPs with a size of 22.3 ± 3 nm, and synthesizes Nanocatalyst is highly active for the synthesis of critical biological 2-arylbenzimideazole. It has been used for the production of intermediates in molecular growth for pharmaceutical and biological purposes. Basavegowda et al. (2014) also reported AuNPs of 15–20 nm size with biomedical applications photosynthesized with the help of fruit extract of *Hovenia dulcis*. The molecules present in the fruit extract reduced the gold metal ions in AuNPs due to a change in solution color within 30 min. In order to generate AuNPs, the *Citrus maxima* fruit extract underwent green synthesis. At 535 nm, the UV visible spectra showed the highest peak and FTIR analysis showed a peak of 1658 cm^{-1}, which corresponds to the C=C double biomolecular bond vibration modes.

The reduction agent is flavonoids, terpenes and vitamins, among which chloroauric acid has shown a peak of 1376 cm^{-1}, which could be attributed to the axial vibration of the C–N bonds in the acid (Yu et al., 2016). In the presence of *Prosopis farcta* fruit extract as a reducing agent, Salari et al. (2019) stated that the biosynthesis of silver nanoparticles (AgNPs) was achieved. The analysis shows that in plant-AgNPs the total phenolic compounds and total flavonoids were higher than in plant extract alone. Compared to *P. farcta* fruit extract alone, plant-AgNPs exhibited greater antioxidant and antibacterial activity. Nakkala et al. (2016) documented the synthesis of AuNPs with data on their in-vitro antioxidant and catalytic activity using *Piper longum* fruit extract. The researchers concluded that these AuNPs are useful in cleaning toxic dyes in industrial effluents with strong catalytic activities.

2.3 Seed extract

The synthesis of AuNPs using *Abelmoschus esculentus* aqueous seed extract has been documented. The outcomes described in the AuNPs synthesis played a vital role in the OH functional group present in the extract. The synthesized nanoparticles with a spherical size range of 45–75 nm were found. The antifungal activity of AuNPs was tested using standard diffusion methods against different types of fungi (Jayaseelan et al., 2013). Venkateswarlu et al. (2014) used *Syzygium cumini* seed extract for the

synthesis of iron oxide nanoparticles as a reducing agent and sodium acetate as a stabilizing agent. X-ray diffraction findings indicate that spherical magnetic NPs have been synthesized. TEM findings showed that the diameter of the cubic structure was 9–20 nm. Analysis of Bruner-Emmett-Teller (BET) gives a surface area of 3517 m^2/g of synthesized FeO NPs and particles have been classified as mesoporous. In the field of water and wastewater remediation, synthesized FeO NPs can be used for the removal of toxic dyes. Azizi et al. (2017) prepared AgNPs in aqueous *Citrullus colocynthis* seed extract as a reducing and stabilizing agent. Biosynthesized AgNPs presented functional antibacterial activities against *Staphylococcus aureus*, Methicillin resistant *S. aurous*, *Pseudomonas aeruginosa,* and *Escherichia coli*. A green approach to the synthesis of AgNPs using an aqueous extract of *Durio zibethinus* seed was developed by another study and its antibacterial, photocatalytic and cytotoxic effects were determined. Surface Plasmon Resonance confirmed the formation of AgNPs with a maximum absorbance (λ_{max}) of 420 nm. SEM and TEM images showed that AgNPs were rod-shaped and spherical, with a size range between 20 and 75 nm. AgNPs demonstrated antibacterial activity against brine shrimp and demonstrated stronger photocatalytic action against blue methylene. In the future, synthesized AgNPs could be used in the fields of water, pharmaceuticals, biomedicine, biosensors and nanotechnology (Sumitha et al., 2018).

2.4 Bark extract

Bark extract is used for the synthesis of different metallic nanoparticles Table 2. 18.2 nm average spherical AuNPs with face-centered cubic structure synthesized using *Eucommia ulmoides* bark extract demonstrated excellent photocatalytic activity for the decolonization of an azo dye, cango red, and 179 reactive yellow modal compounds (Guo et al., 2015). Due to the presence of biomolecules surrounding the AuNPs core, the DLS calculation showed a greater scale. In addition, Yallappa et al. (2013) used the plant extract of *Terminalia arjuna* bark for the synthesis of CuO NPs within 23 nm, the size of particles. It is important to note that the *Mimusops elengi* bark extract was used at room temperature for the green synthesis of AuNPs. The polyphenols present in the extract of the bark were both a reduction and a stabilizing agent. As an important catalyst for the reduction of 3-nitrophenol and 4-nitrophenol to the corresponding aminophenol, synthesized AuNPs have been used (Majumdar et al., 2016). A facile and green route for the synthesis of PdNPs was carried out from $PdCl_2$ solution (Kora and Rastogi, 2018). The investigator as a reducing and stabilizing agent used gum ghatti, a non-toxic, sustainable plant polymer obtained from the *Anogeissus latifolia* tree. The fabricated particles show excellent catalytic activity in the dye degradation and environmental remediation. A successful study was carried out that synthesized AgNPs using spruce bark (*Picea abies* L.) as a bio resource of cost-effective nonhazardous reducing and stabilizing compounds. The effects of different factors like the reactants concentration, ratio extract/salt silver nitrate and time of incubation on the controlled synthesis of AgNPs were explored (Tanase et al., 2020). The synthesis of CuONPs was reported by Vellora et al. (2013), using

Table 2 Biogenic synthesis of metal/metal oxide nanoparticles by plant parts of seed, bark, root and flower extract.

Biogenic agent	Green NPs	Size (nm) and shape	Applications	References
Seed extract				
Abelmoschus esculentus	AuNPs	45–75 nm, Spherical	Antifungal agent	Jayaseelan et al. (2013)
Syzygium cumini	FeO Nps	9–20 nm, Cubical	Wastewater remediation	Venkateswarlu et al. (2014)
C. colocynthis	AgNPs	23 ± 2 nm	Biomedical applications	Azizi et al. (2017)
Pimpinella anisum	AgNPs, AuNPs	18–22 nm,16-22 nm, Spherical	Antifungal and antibacterial agent	Zayed et al. (2020)
Cucurbita pepo	TiO2 NPs	> 100 nm, Tetragonal	Various applications	Abisharani et al. (2019)
Durio zibethinus	AgNPs	20–75 nm, Spherical and rod	Antibacterial, photocatalytic	Sumitha et al. (2018)
Bark				
E. ulmoides	AuNPs	18.2 nm, FCC	Photocatalyst for environmental remediation	Guo et al. (2015)
T. arjuna	CuO NPs	23 nm, Spherical	Antioxidant	Yallappa et al. (2013)
M. elengi	AuNPs	9–14 nm, Spherical	Efficient catalyst for 3-nitrophenol and 4-nitrophenol reduction	Majumdar et al. (2016)
A. latifolia	PdNPs	4.8 ± 1.6 nm, Spherical	Antioxidant and catalyst	Kora and Rastogi (2018)
Cochlospermum gossypium	AgNPs, AUNPs, PtNPs	5.5 ± 2.5 nm, FCC 7.8 ± 2.3 nm, FCC 2.4 ± 0.7 nm, FCC		Vinod et al. (2011)
Karaya gum	CuO NPs	4.8 nm, Monoclinic	Antimicrobial against *E. coli*	Vellora et al. (2013)
S. malabarica	AuNPs	12 ± nm, FCC crystalline	Catalytic application	Ganapuram et al. (2015)
T. arjuna	AuNPs	20–50 nm, Spherical	Neuroprotective potential via antioxidant, anticholinesterase, and antiamyloidogenic effects	Suganthy et al. (2018)
P. abies L.	AgNPs	226 nm, compact blocks	Antibacterial agent	Tanase et al. (2020)

Erythrina caffra	AgNPs	< 16 nm, Spherical	Antibacterial agent	Shaik et al. (2019)
Cinnamomum verum	MnNPs	50–100 nm, Spherical	Photo catalysts and antimicrobial agents	Kamran et al. (2019)
Eucalyptus globulus	AuNPs	20.1–100.9 nm, Spherical	Establishment of the reduction conditions of these eco-friendly approaches	Pinto et al. (2017)
Root extract				
M. citrifolia	AgNPs	30–55 nm, Spherical	Have an exceptional cytotoxic effect on HeLa cells	Suman et al. (2013)
C. barometz	AuNPs	AuNPs 6n, AgNPs 28 nm, Spherical	antimicrobial activity against Escherichia, ***Staphylococcus aureus***, ***Salmonella enterica*** etc.	Wang et al. (2017)
Lantana camara	AuNPs	11–32 nm, Spherical	Antioxidant and cytotoxic properties	Ramkumar et al. (2017)
Arctium lappa burdock	AgNPs AuNPs	21.3 nm Spherical, 24.7 nm multi shapes	Antimicrobial agent and catalyst for degradation of pollutants	Nguyen et al. (2018)
A. racemosus	AgNPs	10–17 nm, Spherical	Biomedical and biopharmaceutical applications	Vijay Kumar et al. (2019)
Berberis V. vigenis	AgNPs	30–70 Spherical	Antibacterial agent	Behravan et al. (2019)
Flower extract				
N. arbor-tristis	ZnO NPs	12–32 nm, Crystalline nature	Antifungal agent	Jamdagni et al. (2018)
Hibiscus rosa sinensis	NiNPs			Kar and Ray (2014)
Origanum vulgare L	PdNPs	2.2 nm, Spherical	Catalytic application	Shaik et al. (2017)
Bauhinia acuminate	AgNPs	17 nm uniform	Osteogenic differentiation and proliferation on MSCs,	Hu et al. (2019)
Mangifera indica	AgNPs	10–20 nm, Spherical	Antibacterial agent	Ameen et al. (2019)

Karaya gum and $CuCl_2.2H_2O$ at 75°C. There was an average particle size of 4.8 nm. Antimicrobial activity against *E. coli* was shown in the synthesized CuO NPs.

In addition, stable AuNPs were synthesized as both reducing and capping agents by *Salmalia malabarica* gum. In the UV visible spectrum, a peak at 520–535 nm characterized the synthesized AuNPs. The XRD results showed that the synthesized AuNPs with face-centered cubic geometry were crystalline. The average particle size of AuNPs was 12 ± 2 nm in the TEM results. The synthesized particles applied as catalysts for the reduction of methylene blue and Congo red (Ganapuram et al., 2015).

2.5 Root extract

Suman et al. (2013) synthesized AgNPs using the root of *Morinda citrifolia*. The formation of AgNPs confirmed by UV.Visible spectroscopy at 413 nm. The TEM analysis showed that these AgNPs are 30–55 nm spherical with a scale. Further, Wang et al. (2017) and Ramkumar et al. (2017) also reported the biosynthesis of AgNPs using *Cibotium barometz* and *Lantana camara* root extract, respectively. Vijay Kumar et al. (2019) reports simple and economical eco-friendly and green synthetic route by employing AgNO3 source and *Asparagus racemosus* root extract as a synthesis reducer and capping agent for crystalline and uniformly spherical nanosilver particles in a dimensional range of 10–17 nm under optimized conditions. The synthesized AgNPs were evaluated against microbial strains (Table 2).

2.6 Flower extract

In the another study, ZnO NPs is synthesized using *Nyctanthes arbor-tristis* aqueous flower extract (Jamdagni et al., 2018) as a biological reducing agent. The study reports that these NPs ranged in size from 12 to 32 nm. The NPs have, however, been tested for their antifungal ability and have been found to be active against phytopathogens with the lowest minimum inhibitory value of 16 lg/mL. Shaik et al. (2017) reported another simple eco-friendly synthesis of PdNPs by using an aerial portion of the *Organum vulgare* L (OV) extract as a bio-reducing agent. The present phytochemicals in OV extract accountable for the reduction as well as stabilization. FTIR results confirm that the OV act as bio reductant and functionalizes the NPs. Also, synthesized PdNPs were applied as a catalyst for selective oxidation of alcohols. By using Hibiscus Rosa Sinensis petals as a bio-template and reducing agent, Kar and Ray (2014) developed a new green method for the biosynthesis of NiNPs. An alteration of the end product toward the magnet confirmed the formation of NPs. Synthesized NPs were stable a period of 20 days (Table 2).

3 Synthesis from agri-waste

Globally, a large number of different sources of Agri- waste derived from horticulture are produced, and after a sustainable source of biochemical compounds. Developing

new recycling and Agri-waste utilization procedures, create unique opportunities for producing nanoparticles. Various organic compounds such as polyphenols, flavonoids, terpenoids, and vitamins are found in the Agri-waste content (Saratale et al., 2018a), which act as templating agents. The reduction of metal salts is the cause of the various functional groups found in these compounds. The waste materials thus serve as bio-factories (Sharma et al., 2019).

Yang et al. (2014) report the AuNPs have been synthesized using mango peel extract. In the size range of 6.03–18.1 nm, the particles were monodispersed and without biological toxicity. In the presence of grape seed extract, spherical and polygonal-shaped AgNPs with an average diameter of 25–35 nm were generated by reducing Ag + ions into NPs. These nanoparticles showed effective antibacterial activity against bacteria that were gram-negative and gram-positive (Xu et al., 2015). The microwave-assisted method has been applied to the fabrication of an AgNPs, from orange peel extract with an average diameter of 7.36 ± 1.06 nm. Spherical nanoparticles were obtained, and compounds present in extract act as capping molecules (Kahrilas et al., 2014). Chamsa-ard et al. (2019) reported an eco-friendly method for biosynthesis of AuNPs from waste *Citrullus lunatus var* (watermelon). The antibacterial properties of various extracts and synthesized. AuNPs were assumed by Kirby-Bauer resistivity method. The study has shown produced AuNPs with antibacterial activity towards both *E. coli* and *Staphylococcus epidermidis*. Dang et al. (2019) studied eco-friendly and room temperature procedure for the biosynthesis of AuNPs from waste *Macadamia nutshells*. The characterization results reveal AuNPs were crystalline, size from 50 to 2 µm and had spherical, triangular and hexagonal morphology. Biosynthesized AuNPs showed antibacterial activity against *E. coli* and *Staphylococcus epidermidis*. Another study reports Cu/Cu_2O/CuO NPs, were synthesized by polyphenols of pomegranate extract for various applications. The results confirmed synthesized nanoparticles exhibited good electrochemical performance towards the electrode surface (Fuku et al., 2020). It is not yet commonly explored to synthesize metal oxide nanoparticles using agro and food waste; the tea waste template has been used with cuboid or pyramid morphology for the synthesis of magnetic iron oxide (Fe_3O_4) NPs in the 5–25 nm size range. In removing arsenic metal from water, these nanoparticles proved to be very effective (Lunge et al., 2014). In the synthesis of Mn_3O_4 NPS with super capacitive properties, banana peel extract was used (Yan et al., 2014). SEM analysis reveals particles within average diameter 20–15 nm. *Punica Grantum* fruit peel for the facilitated ultrafast synthesis of AuNPs, showing the development of the extract, suggesting a shift in color to wine red. According to SEM research, the SPR of AuNPs showed 530 nm and spherical type (Ganeshkumar et al., 2013). Bibi et al. (2017) used *Punica granatum* peel extract as a reducing agent to synthesize CoO NPs, and cobalt nitrate hexahydrate is a precursor. Kumar et al. (2014a,b) report the formation of ZnO NPs induced by *Chrysopelea paradisi* peel extracts. The biomolecules flavonoids, carotenoid react with $ZnSO_4$ salt solutions, ZnO NPs synthesized after completion of the reaction. Orange peel pith, orange fruit waste is proper support and reducing agent for green synthesis of AgNPs. These NPs have a good size distribution, about 5 nm in a spherical shape by

the bioreduction method (Lopez-Tellez et al., 2018). Another study has also reported the synthesis of PtNPs using *Punica granatum* peel extract with size 16–23 nm in a spherical shape (Dauthal and Mukhopadhyay, 2015). The global Water Pollution is highly challenging and requires urgent attention. It is pertinent to explore possibilities in wastewater treatment with an environmentally friendly route. An efficient method can be explored, where biosynthesis of nanoparticles by agricultural waste can further use its potential in cleaning the environment. Cu_2O NPs were synthesized using Fehling solution and sugar cane bagasse extract as reducing and capping agent. Their catalytic efficiency was studied by carrying out the degradation of different toxic dye dyes present in the wastewater (Yadav et al., 2020).

The orange (*Citrus* × *Clementina*) peel aqueous extract (OPE) reported by Saratale et al. (2018b) was used for the one-pot green AgNPs synthesis with an average particle size of 15–20 nm. The synthesized AgNPs were found to be stable for up to 6 months without their properties being altered. The synthesized AgNPs are also highly effective against different microbial pathogens and demonstrated anticancer activity against rat glial tumor C6 cells. In order to synthesize Mn3O4 NPs ranging in size from 20 to 50 nm and having super-capacitive properties, banana peel extract was also used successfully. Mn3O4 is one of the most stable manganese oxides with a wide range of interesting properties, from catalysis to high-density magnetic storage media (Ibrahim, 2015). The study found that the synthesis and stabilization of NPs requires biochemical constituents such as pectin, cellulose, hemicellulose, and lignin. Table 3 provides the descriptions of such studies.

4 Factors influencing the biosynthesis of nanoparticles

The characterization and application of nanoparticles through biosynthesis is deeply influenced by several factors. Many scientists have documented a change like the synthesized nanoparticles according to the type of reactants used in the synthesis process (Somorjai and Park, 2008). Some of these studies have documented the dynamic existence of synthesizing nanoparticles and their types of indications and consequences by changing time, biosynthesis and other variables (Pennycook et al., 2012; Kulkarni et al., 2015). Temperature, solution pH, salt solution concentration, and extracts used are other significant factors that influence the synthesis of the nanoparticles (Salari et al., 2019; Zayed et al., 2020). Below, some of the critical factors are discussed.

4.1 pH of solution

In the biogenic synthesis of nanoparticles, the pH of the reaction solution has an important role. Several researchers have proposed that the pH of the solution medium affects the synthesis rate, shape and size of nanoparticles (Armendariz et al., 2004; Malassis et al., 2016). It is due to the formation of nucleation Center, which varied with the addition of solution pH. Kumar et al. (2019) reported that the yield of synthesized AgNPs applying *Cinnamon zeylanicum* bark extract, increased, which increases

Table 3 Biogenic synthesis of metal/metal oxide nanoparticles by agri-waste materials.

Biogenic agent	Green NPs	Size (nm) and shape	Applications	References
Mango Peel	AuNPs	6.03 ± 2.77 to 18.01 ± 3.67 nm		Yang et al. (2014)
Grape Seed	AgNPs	25–35 nm, Spherical, Polygonal	Antibacterial agent	Xu et al. (2015)
Orange Peel	AgNPs	7.36 ± 8.06 nm, Spherical		Kahrilas et al. (2014)
Tea waste template	Fe_3O_4 NPs	5.25 nm, Cuboidal pyramid	Removal Arsenic (As) from water	Lunge et al. (2014)
Banana Peel	Mn_3O_4 NPs	20–50 Tetragonal crystalline		Yang et al. (2014)
Punica granatum fruit peel	AuNPs	Spherical	Use in cancer targeted drug delivery	Ganeshkumar et al. (2013)
Punica granatum fruit peel	CoO NPs	40–80 nm, uniform shape	Photocatalyst	Bibi et al. (2017)
Chrysopelea paradisi peel	ZnO NPs			Kumar et al. (2014a,b)
Orange Peel pith	AgNPs	5 nm, Spherical	Antibacterial agent	Lopez-Tellez et al. (2018)
Punica granatum fruit peel	PtNPs	16–23 nm, Spherical	Catalytic application	Dauthal and Mukhopadhyay (2015)
Punica granatum fruit peel	AgNPs	20–40 nm, Spherical	Development of a drug for colon cancer that also has antibacterial activity	Devanesan et al. (2018)
Citrus juices	FeNPs	3–300 nm, Irregular Cylindrical Spherical	Environmental remediation	Machado et al. (2014)
Waste Watermelon	AuNPs	100 nm–2.5 μm, Sphere, hexagonal, triangular	Pharmaceutical applications	Chamsa-ard et al. (2019)
Sugarcane bagasse	Cu_2O NPs	38.12 nm, Irregular	Photocatalytic degradation of toxic dyes	Yadav et al. (2020)
Macadamia nutshells	AuNPs	50 nm-2 um, Sphere, hexagonal, triangular	Pharmaceutical applications	Dang et al. (2019)
Pomegranate peel extract	Cu, Cu_2O, CuO NPs	5–20 nm, Nearly spherical	Capacitors and catalysts	Fuku et al. (2020)
Walnut shells (WS1,WS2,WS3)	CuNPs	15-20 nm,60–80 nm, Aggregated	Pharmaceutical and food applications	Mehdizadeh et al. (2020)
Orange (*Citrus* × *Clementina*) peels	AgNPs	15–20 nm, Spherical	Antibacterial activity against human pathogens, activity against antioxidants, activity against cancer	Saratale et al. (2018b)
Skin of a grape, stalk and seeds	AuNPs	20–25 nm, Quasi-sphere	–	Krishnaswamy et al., 2014
Rice bran	AuNPs	Around 50–100 nm, Spherical	–	Malhotra et al., 2014
Watermelon rind	PdNPs	90 nm, Spherical	Applied as catalyst	Lakshmipathy et al. (2015)
Banana Peel	Mn_3O_4 NPs	20–50 nm	Catalytic application	Ibrahim (2015)

the concentration of extract and pH of the solution and produced more spherical nanoparticles. In another study, lower pH favored the synthesis of monodispersed spherical AuNPs (Oza et al., 2012). Whereas a peer extract showed under the alkaline condition to yield hexagonal, and triangular AuNPs but in acidic conditions reports, no formation of nanoparticles Ghodake et al., 2010). Yumei et al. (2017) reported the *Arthrobacter sp*., assisted biosynthesis of an AgNPs can be modulated by pH of the reaction mixture at 1 mM $AgNO_3$ concentration synthesized face-centered cubic structure AgNPs with size between 9 and 72 nm at 70°C temperature and pH 7–8.

However, no formation of AgNPs reported below 5 and above 8 pH of Solution. Shankar et al. (2003) also communicate that the extract of *Aloe Vera* developed Au−Ag core NPs in different sizes and shapes by varying the medium pH. Besides, the dimension of *A. indica* leaf extract induced biosynthesized CuNPs is affected by the pH of the solution (Nagar and Devra, 2018a,b). Capping and stabilizing ability is dependent on the charge of biomolecules, which might affect by pH. It was observed that in acidic pH, CuNPs were not formed. It indicates acidic pH suppresses the synthesis rate. At higher pH (6–6.6), a greater number of small-sized CuNPs were synthesized due to the availability of functional group for copper binding. Zhan et al. (2011) studied the effect of pH on the biosynthesis of AuNPs by *Cacumen platycladi* leaf extract. As a result, the size of AuNPs decreases, while the peak absorption rate rises with the rise in pH. They also reported that elevated pH contributes to a rapid reduction of Au + 3 ions, enhances homogeneous nucleation, and decreases the growth of anisotropy. The slow reduction rate observed under acidic conditions, on the other hand, resulted in heterogeneous nucleation and secondary nucleation of small Au seeds.

4.2 Extract from plants/biomass dosage

The plant extract/biomass concentration also affected the synthesis efficiency of nanoparticles. Several studies have shown that increased dosage of extracts increases the production of nanoparticles and changes the shape of NPs (Zheng et al., 2013; Balamurugan et al., 2014). Therefore, determining the optimum extract dosage for synthesis is often necessary. In addition, by adding 0.5 M $FeNO_3.5H_2O$ to the green tea extract, Markova et al. (2014) prepared FeII, III polyphenol complex nanoparticles with a size of 70 nm in diameter in a 1:5 volume ratio. In various studies, researchers report the zero-valent iron (II, III) polyphenol complex using green tea extracts. Therefore, nano iron synthesis can vary in size and properties due to changes in the method of synthesis and extract-to-salt ratio. Similar findings were found in the Nagar et al. (2016) study, which evaluated the percentage effect of neem leaf extract on the size of AgNPs. Nanosize AgNPs synthesized at room temperature using different percentage of neem leaf extract. The TEM results reveal that increase in the leaf extracts up to optimum percentage (10%), the particle size decreases (20–9 nm). After that increase in particle size with an increasing percentage of leaf extract (15%), suggesting that too many reducing agent cause aggregation of AgNPs (Fig. 3). Highly stable and spherical ZnO NPs were synthesized when Zinc

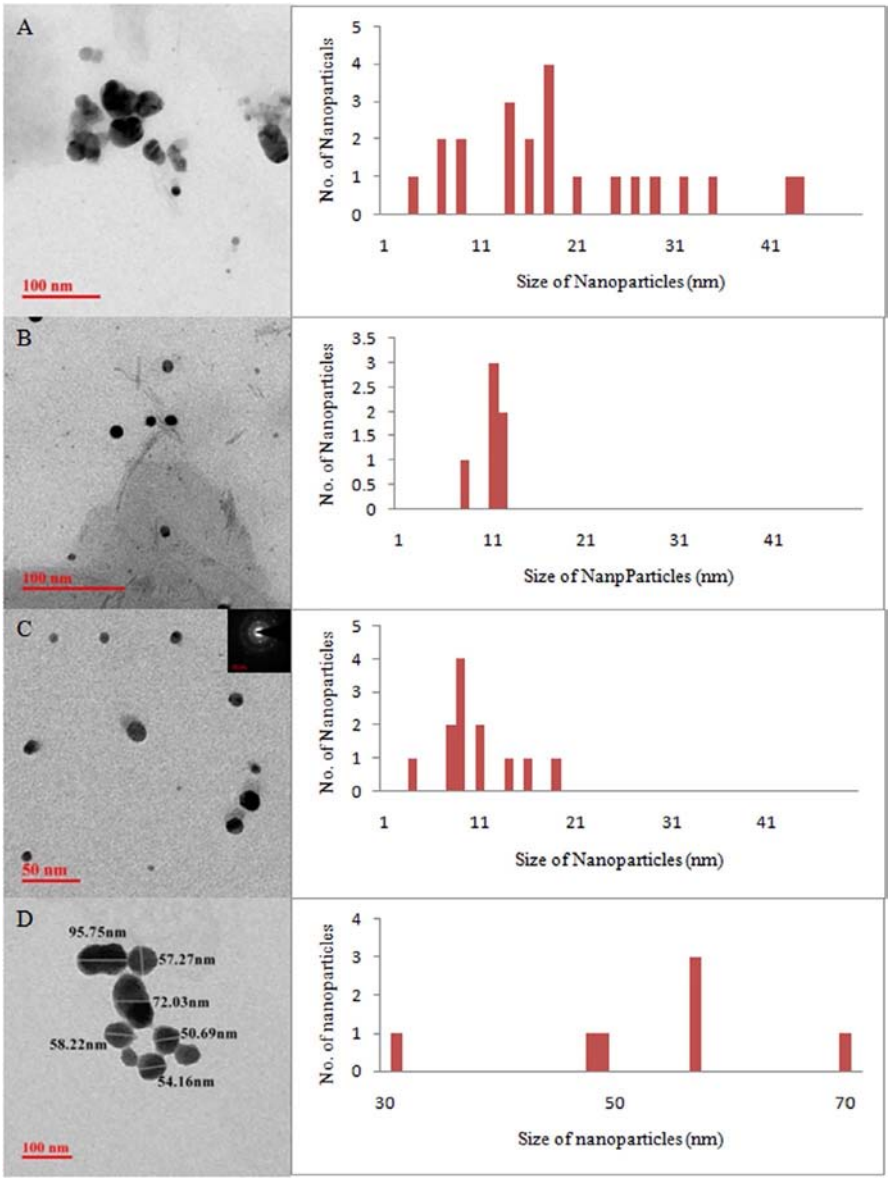

FIG. 3

TEM images with histogram of synthesized silver nanoparticles at different percentage of leaf extract (A) 5%, d = 20 nm, (B) 7%, d = 11 nm, (C) 10%, d = 9 nm, (D) 15%, d = 56 nm.

From Nagar, N., Jain, S., Kachhawah, P., Devra, V., 2016. Synthesis and characterization of silver nanoparticles via green route. Korea J. Chem. Eng., (Springer) 33, 2990–2997.

nitrate and Aloe-Vera leaf extract were used (Sangeetha et al., 2011). More than 95% conversion of nanoparticles with more than 25% aloe leaf extract was achieved in this analysis. The ZnO NPs generated were polydispersed and ranged in average size from 25 to 40 nm. The characterization showed that the particle size could be controlled by changing concentration of extract leaf.

4.3 Effect of precursor salt solution

The initial concentration of precursor salt also affected the morphology and process of synthesis. The leaf extract of *Diospyros kaki* has been investigated as a reduction agent for the biosynthesis of PtNPs from the aqueous solution $H2PtCl_6.6H_2O$ (Song et al., 2010) at 95°C temperature. The different characterization results reveal that average particle size ranged from 2 to 12 nm, depending upon the concentration of precursor salt. Meanwhile, Nagar and Devra (2018a) reported the initial precursor salt concentration also affected the particle size of nanoparticles during the synthesis process. The study includes that green synthesis of CuNPs by *A. indica* leaf extract is highly depending on the concentration of precursor salt $CuCl_2.2H_2O$. It was confirmed that by SEM analysis, the concentration of the salt solution is increased from 6×10^{-3} to 7.5×10^{-3} M, the particle size of NPs decreases, after that particle size increase with increased concentration of the salt solution. It may be due to a concentration of salt increases, the copper nuclei rises, and smaller particle size are obtained correspondingly. However, an excess number of nuclei will be generated at high salt concentration, resulting in the growth of particles, due to agglomeration of nuclei (Fig. 4). Din et al. also reported that increasing concentration of the precursor salt, the size of the CuNPs also increased.

4.4 Reaction temperature

Temperature is also an important factor affecting the synthesis scale, shape and rate of NPs. Nucleation center formation increases at higher temperatures, which in turn increases the rate of biosynthesis. Raju et al. (2011) reported that the gold nanoparticles synthesized using *Cymbopogon flexuosus* leaf extract showed that high temperatures could lead to spherical NPs and nano triangles being formed. Lower reaction temperature, therefore, generally increases the formation of nanotriangles. Nagar and Devra (2017) also describe the effect of temperature on biosynthesized CuNPs by *A. indica* leaf extract. It was observed that below 65°C of reaction temperature the CuNPs not formed. The reduction rate considerably increases by increasing reaction temperature from 65 to 85°C, but at the higher temperature (<85°C) the synthesis rate is too high to control particle size. Therefore, CuNPs were agglomerated. In an effort to investigate the effect of temperature, Iravani and Zolfaghari (2013) on the reaction mixture of *Pinus eldarica* bark extract and $AgNO_3$ at four temperatures (25, 50, 100, and 1500°C). The authors found that the reaction temperature increased, absorption increased and the size of AgNPs decreased.

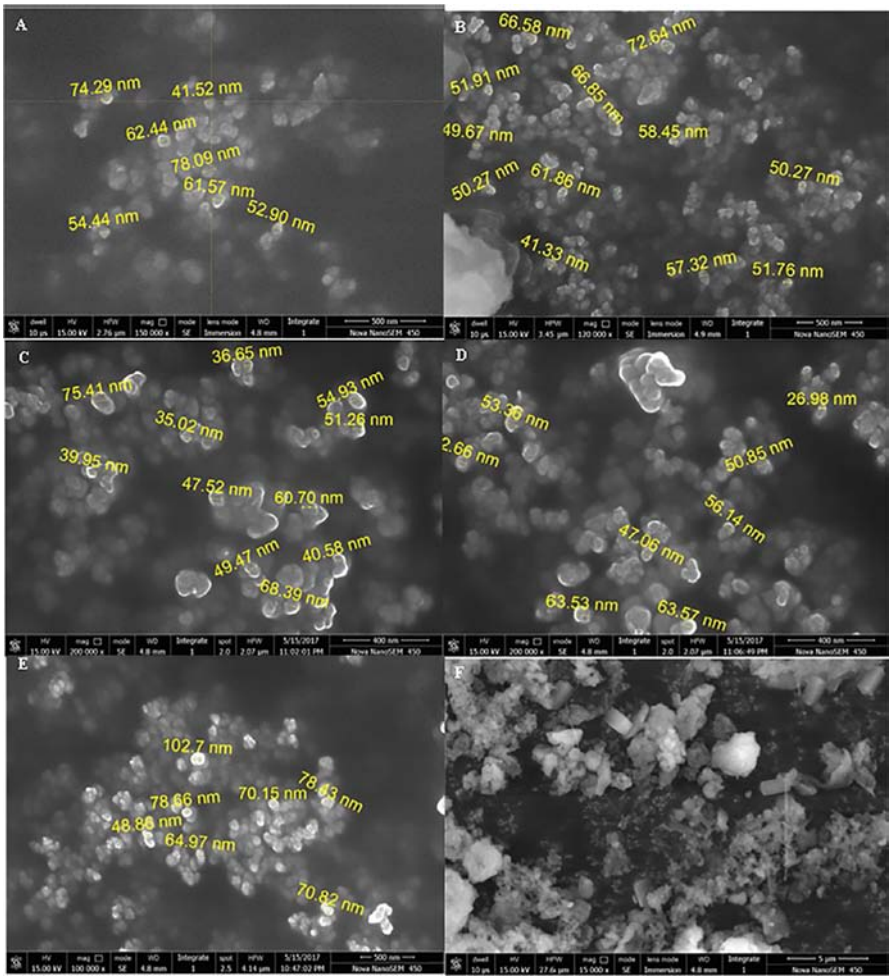

FIG. 4

SEM images of synthesized copper nanoparticles at different initial concentration of $CuCl_2$ (A) 6×10^{-3} M, (B) 6.5×10^{-3} M, (C) 7×10^{-3} M, (D) 7.5×10^{-3} M, (E) 8×10^{-3} M, (F) 10×10^{-3} M.

From Nagar, N., Devra, V., 2018. Green synthesis and characterization of copper nanoparticles using A. indica leaves. Mater. Chem. Phys. 213, 44–51.

4.5 Period of reaction time

The size, shape and rate of biomaterial synthesis of nanoparticles are also greatly influenced by the period of reaction time and suspension medium. To define the concentration of nanoparticles and the formation of nanoparticles, the optimum time produces the highest absorbance peak (Jain et al., 2015). Authors report the synthesis of CuNPs using ascorbic acid as reducing and capping agent and UV Visible

spectroscopy results indicates that the absorption peak of spectra can be observed after 2 h of reaction. There was an intensity increase with the reaction progressing; this was due to the growth of copper nanoparticles. The synthesis process was completed after 24 h (Fig. 5A). Whereas Nagar et al. (2016) reported the *A. indica*, extract assisted biosynthesis of AgNPs within 2 h. The UV–Vis spectra were recorded after

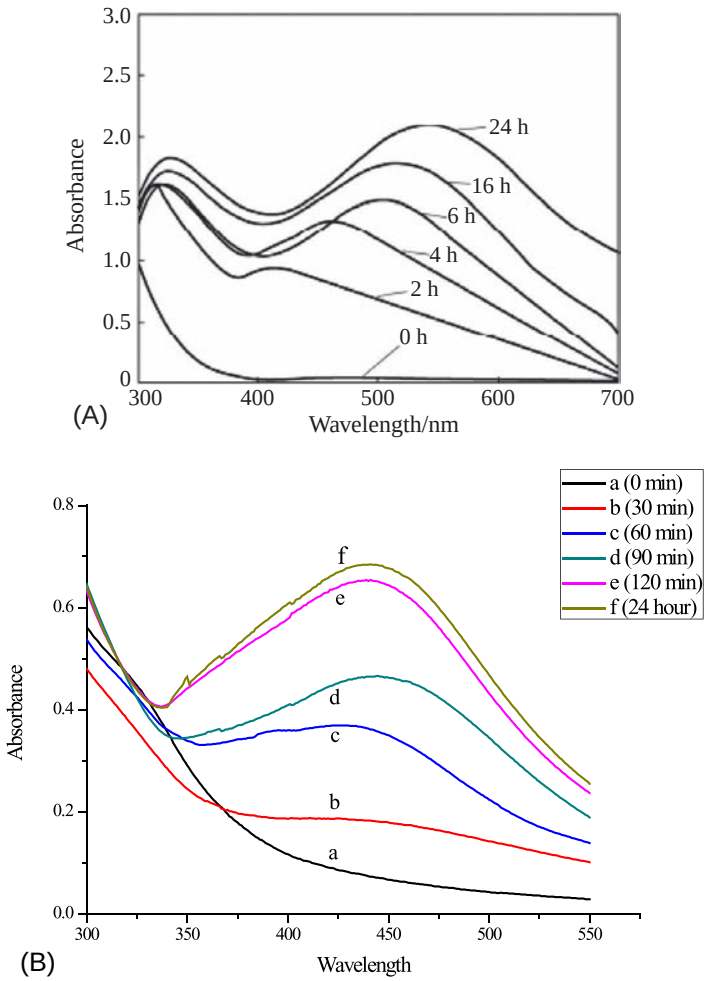

FIG. 5

(A) UV spectra recorded as a function of reaction at different wavelength versus absorbance during synthesis of copper nanoparticles at different time intervals. (B) UV spectra recorded as a function of reaction at different wavelength versus absorbance during synthesis of silver nanoparticles at different time intervals.

(A): From Jain, S., Jain, A., Kachhawah, P., Devra, V., 2015. Synthesis and size control of copper nanoparticles and their catalytic application. Trans. Nonferrous Metal Soc. China (Elsevier) 25, 3995–4000; (B) From Nagar, N., Jain, S., Kachhawah, P., Devra, V., 2016. Synthesis and characterization of silver nano-particles via green route. Korean J. Chem. Eng. (Springer) 33, 2990–2997.

different time intervals from the initiation of the reaction, as shown in (Fig. 5B). It is observed that the reduction of the metal ions occurs rapidly within 30 min addition of neem leaf extract to metal ion solution and steadily increases in intensity as a function of time of reaction without any shift in the peak at 433 nm. Nazeruddin et al. (2014) concluded the rapid synthesis of AgNPs by seed extract of *Coriandrum sativum* within 1–2 h, compared to 2–4 days, supported by microorganisms. Noruzi et al. (2011) also announced that the meditated synthesis of AgNPs by Rosa hybrid petal was completed within 5 min. Dwivedi and Gopal (2010) states that within 15 min of reaction, *Chenopodium album* leaf extract assisted synthesis of Ag and AgNPs began. They also noticed that the sharing of peaks in both Ag and AgNPs is highly influenced by increased contact time.

4.6 Capping agents

In the biosynthesis of nanoparticles, Capping Agents have a silent function. Moreover, by regulating the size and morphology, it imparts functional properties and prevents agglomeration by shielding the surface. Since aggregation reduces interfacial free energy, particulate matter, reactivity and surface area, the stability of the nanoparticle over its overall life span must therefore be maintained. Different surfactants were used to adjust the desired size and shape of the nanoparticles (Padalkar et al., 2010). The commercial surfactants were dangerous to the environment. Therefore, biocompatible eco- friendly stabilizing and keeping agents such as vitamins, polysaccharides (Virkutyte and Varma, 2011) citric acid, phyto-chemicals and biodegradable polymers were applied as capping agents in the synthesis of metallic nanoparticles.

4.7 Pressure

The pressure is another critical factor that influence the morphology of synthesized and NPs when applied to the reaction medium (Abhilash and Pandey, 2012). The rate of metal ion reduction using biological agents is faster at ambient pressure conditions (Tran et al., 2013).

4.8 Environment

In deciding the formation and nature of nanoparticles, Sarathy et al. (2008) confirmed that the environment plays an important role. In several conditions, each single particle easily becomes the nanoparticles of the core shell by absorbing the adjacent material or reacting through the oxidation or corrosion phase with other environmental reactants. Researchers also stated that the environment could considerably influence the physical structure and chemistry of the synthesized nanoparticles. There is a simple and immediate shift in the crystalline nature of ZnS NPs when the atmosphere changes from wet to dry. The chemical nature of cerium nitrate nanoparticles is influenced by the presence of peroxide in the suspended medium (Kuchibhatla et al., 2012).

5 Conclusion and future prospective

For the synthesis of metal nanoparticles, various chemical, physical, and biological synthetic methods have been used. Most of these problems are stability, nanoparticle aggregation, crystal growth regulation, morphology and distribution of size. The plant-based metal nanoparticles and Agri waste are more stable compared to those formed by other species. In addition, the use of a simple and healthy green approach in the production of well distributed metal nanoparticles for scale-up and industrial production. Many plant and waste material biomolecules, such as proteins/enzymes, polysaccharides, alkaloids, alcoholic compounds, may be involved in the biodegradation, formation and stabilization of metal nanoparticles. The future of research will be to optimize the reaction conditions and to engineer recombinant organisms for the processing of high quantities of proteins, enzymes and biomolecules involved in nanoparticle synthesis. It will help to enhance nanoparticle production by understanding the enhanced biochemical pathway in plant heavy metal detoxification, aggregation and resistance. The potential approach to improving the efficiency of these species in nanoparticle synthesis is the genetic engineering of plants with improved metal tolerance and accumulation capabilities.

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